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**ALLIED PAPER, INC./PORTAGE CREEK/
KALAMAZOO RIVER SUPERFUND SITE**

**REMEDIAL INVESTIGATION/
FEASIBILITY STUDY**

TECHNICAL MEMORANDUM 10

**SEDIMENT CHARACTERIZATION AND
GEOSTATISTICAL PILOT STUDY
VOLUME I OF IV**

**ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER
SUPERFUND SITE
KALAMAZOO, MICHIGAN**

February 2002

Table of Contents

1.0	INTRODUCTION	4
1.1	Scope of Technical Memorandum No. 10	4
1.2	Kalamazoo River/Portage Creek Description and Background	4
1.3	Objectives of the Sediment Characterization Survey and Geostatistical Pilot Study	4
1.3.1	Sediment Characterization Survey	5
1.3.2	Geostatistical Pilot Study	5
2.0	SEDIMENT CHARACTERIZATION SURVEY	6
2.1	Rationale	6
2.2	Investigation Activities	6
2.2.1	Estimating Volume	8
2.3	Results	9
2.3.1	Summary of Field Observations and Volume Estimates	9
2.3.2	Relationship of Fine-Grained Sediment Deposition to Other Observed Characteristics	12
2.4	Preliminary Findings	13
2.4.1	Applicability of Stratified Sampling Approach	13
3.0	GEOSTATISTICAL PILOT STUDY	14
3.1	Rationale	14
3.2	Investigation Activities	15
3.2.1	Field Activities	15
3.2.2	Analytical Data Summary	15
3.2.3	Point Kriging and Mapping	16
3.2.4	QA/QC Review of Data	16
3.3	Results	17
3.3.1	Summary of Field Observations	17
3.3.2	PCB Analytical Results	17
3.3.3	Variogram Analysis and Kriging	18
3.4	Preliminary Findings	19
3.4.1	Relationship Between PCB Concentration and Physical Characteristics	19
3.4.2	Geostatistical Analysis	20
4.0	REFERENCES	22

TABLES

1	River Reach Characteristics and Probing Summary
2	Summary of Observed Field Measurements by River Reaches
3	Estimated Volume of Sediments
4	Summary of Total PCB Concentration by Fine And Coarse-Grained Sediments
5	Summary of Total PCB Concentration by River Channel Shape
6	Sample Delivery Group Summary
7	Summary of Pilot Study Probing
8	Summary of PCB Results for Geostatistical Pilot Study

FIGURES

1	Index To Drawings
2	Portage Creek/Kalamazoo River Confluence
3	Kalamazoo River Downstream of Confluence
4	Kalamazoo River Upstream of Plainwell
5	Kalamazoo River Otsego City and Former Plainwell Impoundments
6	Kalamazoo River Former Trowbridge and Otsego Impoundments
7	Kalamazoo River Trowbridge Dam to Allegan City Dam
8	Lake Allegan
9	Kalamazoo River Lake Allegan Dam to Ottawa Marsh
10	Percent of Cores Classified as Containing Fine-Grained Sediment by River Reach.
11	Volume Of Fine- And Coarse-Grained Sediment In The Kalamazoo River
12	Percent Of Cores Classified As Containing Fine-Grained Sediment By Velocity Range
13	Percent Of Cores Classified As Containing Fine-Grained Sediment By Channel Characteristics
14	Sediment Thickness By Velocity Range
15	Sediment Thickness By Channel Characteristics
16	Sample Locations For Geostatistical Pilot Study
17	Geostatistical Pilot Study Sediment Sample PCB Concentration Ranges
18	Geostatistical Pilot Study PCB Concentration Frequency Distribution
19	River Cross Section KPS-17 To KPS-23
20	River Cross Section KPS-28 To KPS-34
21	River Cross Section KPS-49 To KPS-53
22	Geometric Mean Total PCB Concentration With Approximate 95% Confidence Limits Classified By Sample Position Relative To River Geometry
23	Kriged Geometric Mean PCB Concentrations
24	Kriged Geometric Mean PCB Concentrations Plus One Standard Deviation.
25	Kriged Geometric Mean PCB Concentration Minus One Standard Deviation.
26	Along River Channel, Sample Variogram Estimates For Natural Log Transformed Surficial Total PCB Concentration.
27	Across River Channel, Sample Variogram Estimates For Natural Log Transformed Surficial Total PCB Concentration.

Appendices

Appendix A	Summary of Sediment Characterization Field Observations
Appendix B	Transect Cross-Sections
Appendix C	QA/QC Review of Data – Summary of Precision and Accuracy
Appendix D	Data Review Reports
Appendix E	Chain-Of-Custody Forms
Appendix F	Field Notes
Appendix G	Sediment Characterization Field Observations Reported in November 9, 1998 Database

1.0 INTRODUCTION

This document is Final. It is a revised version of a draft Technical Memorandum that was submitted to the MDEQ pursuant to Administrative Order by Consent No. DFO-ERD-91-001. The MDEQ has modified and finalized the Technical Memorandum pursuant to paragraph 30(d) of the Administrative Order by Consent.

1.1 Scope of Technical Memorandum No. 10

Technical Memorandum No. 10, *Sediment Characterization Survey and Geostatistical Pilot Study*, presents a brief background of the Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site (Site), data and findings of the Sediment Characterization Survey (SCS) and the Geostatistical Pilot Study (GPS) performed at the Site. The SCS is summarized in Sections 1 and 2 while the GPS is summarized in Section 3. References are included in Section 4. The first version of this technical memorandum was based on an incomplete SCS database reported in Appendix A. Blasland, Bouck & Lee, Inc. (BBL) provided an updated database to the Michigan Department of Environmental Quality (MDEQ) on November 9, 1998. Appendix G is an updated version of Appendix A. For completeness, the original Appendix A and a new Appendix G (consistent with the updated database) are included with this document. Results and findings reported in this document are based on the 1998 database.

1.2 Kalamazoo River/Portage Creek Description and Background

This section is a brief synopsis based on the Description of the Current Situation report (Blasland & Bouck, 1992), which contains an extensive review of the physical setting and characteristics of the Site.

The Kalamazoo River (River) and Portage Creek (Creek) are located in southwestern Michigan. The main stem of the Kalamazoo River begins in Albion, Michigan at the confluence of the North and South Branches, and then flows northwesterly for 123 miles through Kalamazoo and Allegan Counties to Lake Michigan. The Kalamazoo River drains an approximately 2000-square-mile watershed including nearly 400 miles of tributaries. Portage Creek is a tributary joining the Kalamazoo River at Kalamazoo, Michigan. Portage Creek begins in Portage, Michigan and, including its West Fork, flows a total distance of approximately 18.5 miles. The Site includes approximately 80 miles of the lower portion of the River and the lower three miles of the Creek (Figure 1).

The presence of polychlorinated biphenyls (PCB) was first reported in the River and biota of the river in 1971. This consequently resulted in consumption advisories for fish of the River and Creek. Several subsequent studies have documented the presence of PCB within the surface water, sediments, floodplain soil and biota of both the River and Creek, as well as in landfills adjacent to both surface water bodies.

1.3 Objectives of the Sediment Characterization Survey and Geostatistical Pilot Study

General characterization of sediments of portions of the River and Creek and the GPS were conducted by BBL according to the remedial investigation feasibility study work plan (Blasland and Bouck, 1993a). The SCS describes the channel geometry and spatial distribution of fine- and coarse-grained sediments within a 54-mile reach of the River and two-mile stretch of the Creek. This includes the portion of the River from Morrow Dam downstream to a point 3.7 miles below Calkins Dam and Creek from Alcott Street downstream to the confluence with the River (Figure 1). The GPS provides preliminary information regarding the spatial distribution of PCB in a one-mile, free-flowing reach of the River between Trowbridge and Otsego Dams. Data collected as part of the GPS are used to investigate sampling requirements needed to estimate geometric mean PCB concentration at local scales.

It is anticipated that all or a subset of sediment cores collected in the SCS will be analyzed for PCB as part of a subsequent sampling phase and that the data may be used to evaluate remediation alternatives at the Site. Associations between PCB concentrations and physical characteristics of the river such as velocity, visual classification of sediment grain size and sediment depth are also evaluated. For the purposes of this document, sediment depth is defined to be the depth of sediment that was penetrated by pushing a 5/8-inch galvanized hollow pipe into the sediment until refusal.

1.3.1 Sediment Characterization Survey

The primary objective of the SCS was to document the River width, depth, water velocity and sediment depth, as well as the spatial distribution of fine- and coarse-grained sediments within the Site. The SCS activities involved probing and sampling of sediments to be classified according to visual differences in grain-size. Results, including sediment mapping from this initial sediment survey, will be used to select samples for subsequent analysis for PCB and total organic carbon. Listed below are the primary objectives of this SCS:

- Summarize and document the physical data from the River and Creek;
- Identify the general spatial distribution of visually classified coarse- and fine-grained sediments in the River and Creek; and,
- Estimate total volume of visually classified fine- and coarse-grained sediments in the River and Creek.

1.3.2 Geostatistical Pilot Study

The GPS was conducted to estimate the spatial distribution of geometric mean PCB concentration in the top one foot of sediments within a selected one-mile reach of the River between Otsego City Dam and Trowbridge Dam. The reach selected allowed an assessment of spatial correlation in a single section of the River. The geostatistical procedure known as kriging was used to develop contour maps of geometric mean PCB concentration as well as contour plots of geometric mean concentration plus or minus one standard error. Measurements of physical characteristics of the River were also collected at each location in the GPS area where sediment cores were recovered. Methods used to collect physical characteristics were similar to those used in the SCS. PCB concentration was compared to these physical characteristics.

The primary objectives of the GPS are to:

- Construct a Total PCB Contour Map within the GPS area;
- Develop a semivariogram that describes spatial variability of PCB concentrations in the one-mile study area;
- Assess the implication of various sampling densities on the reliability of future mapping activities; and
- Evaluate associations between PCB concentration and physical characteristics of the River.

The rationale, investigation activities, and preliminary findings of the GPS can be found in Section 3.

2.0 Sediment Characterization Survey

2.1 *Rationale*

The highest concentrations of PCB (as well as other hydrophobic constituents) are expected to be in low-energy depositional zones in association with fine-grained sediments. The SCS was designed to document the spatial distribution of fine-grained deposits within each of the river reaches. Sediments from each probing location were classified as either fine-grained or coarse-grained based on visual observation of both upper four inches and the entire sediment core.

Hakanson (1984) demonstrated the increase in statistical information value obtained by the recognition of factors, such as particle-size distribution and organic carbon content may contribute to the variability of hydrophobic constituent PCB concentration in sediments. The increase in statistical information was illustrated with a reduction in the number of sediment samples required to provide an estimate of mean concentration at a given confidence level. By normalizing PCB concentration to these factors, the random variability was reduced, improving statistical power and understanding of PCB distribution within the sediments.

The SCS was performed to describe river channel geometry, flow velocity and physical characteristics of sediments in 10 reaches (described in Section 2.2) of the River and one reach of the Creek. These separate reaches were determined by BBL based on the hydraulic and hydrologic variations in the River and Creek. A subset of these sediment cores will be analyzed for PCB to evaluate the hypothesis that PCB are associated with physical characteristics. If associations between PCB concentration and physical characteristics such as sediment grain-size prove to be statistically reliable, a stratified sampling approach may be used as a tool that may improve the cost effectiveness of sampling strategies.

The heterogeneity of sediment cores, including visual classification of the top four inches of sediment, was compared to the visual classification of whole cores to determine if a reliable relationship could be established between the top four inches of sediment and deeper sediments (whole core).

2.2 *Investigation Activities*

The SCS was initiated on August 9, 1993. Listed below are the individual reaches of the River and Creek that were included in the SCS.

- Morrow Lake Dam to Confluence of Portage Creek (A1);
- Confluence of Portage Creek to Main Street, Plainwell (A2);
- Main Street, Plainwell to Plainwell Dam (B);
- Plainwell Dam to the Otsego City Dam (C);
- Otsego City Dam to Otsego Dam (D);
- Otsego Dam to the Trowbridge Dam (E);
- Trowbridge Dam to the Allegan City Line (F);
- Allegan City Line to the Allegan City Dam (G);
- Allegan City Dam to the Lake Allegan Dam (H);
- Lake Allegan Dam to 3.7 miles downstream of Lake Allegan Dam (I); and
- Portage Creek from Alcott Street to Confluence with Kalamazoo River (P).

Figure 1 shows the study area and general location within the state of Michigan, Figures 2 through 9 depict the reaches and transect locations including the classification of the top four inches of sediments.

The SCS transects in the river are identified as KPT-1 through KPT-171 and are numbered upstream to downstream. Within each of the eleven reaches, transects were located approximately perpendicular to the riverbanks. Along each River transect, six to eight points were spaced approximately equally across the river. These locations were probed using metal rods and hand-coring equipment. Each sediment core was visually classified as either fine- or coarse-grained based on visual inspection of the sediments in the top four inches of the core, and also based on visual inspection of the general characteristics of the whole core. In cases where more than one stratum was identified, sediment was classified based on the dominant sediment type observed. If no sediment core was recovered, the sediment was usually classified by BBL as coarse. However, no data was collected to verify if this classification is accurate. Locations where no sediment was recovered and the top four inches of sediment was classified as fine-grained included KPT141-5, KPT26-8, KPT3-8, KPT62-2, KPT68-1, KPT86-6, KPT88-5 and PPT15-1. Data in this document were evaluated with the assumption that this classification is correct.

Within the 10 River reaches, transect spacing ranged from a minimum of 104 feet between KPT8 and KPT9 in reach A1 (Morrow Dam to the Confluence with Portage Creek) to 6352 feet between KPT140 and KPT141 in reach H (Lake Allegan). The number of transects per mile ranged from two at Lake Allegan to eight at Allegan City Dam. The highest sampling intensities are near suspected or known PCB sources. This unequal probability sampling design may bias summary statistics associated with these data. It also appears that sampling was less intensive in meandering reaches of the river, perhaps due to the increased sampling effort near point sources that tended to be located on straighter river reaches.

The SCS activities conducted at the Creek reach were conducted on September 1, 1993. A total of 15 sediment probing transects (PPT-1 through PPT-15) were located on the Creek, and they are numbered consecutively downstream to upstream. Transects were spaced at approximately equal distances apart (approximately 600 feet) and perpendicular to the riverbanks. Along each Creek transect, three to five approximately equidistant points were probed using metal rods and hand-coring equipment.

The distances between transects and transect locations were documented by BBL surveyors.

At each River transect, the sediment was probed and sampled by wading, boating, or walking over ice. The River width was determined using standard surveying techniques and instrumentation. The surveying equipment was utilized to keep each probing point on line along each transect, and to measure horizontal distances between them. Markers were placed at each of the probing points. Depending on the River width, a rope was placed across the River to help the samplers stay in position while working from a boat.

At each sampling location, the depth of water was measured by probing with a surveyor's rod. The depth of sediment was then measured by pushing a calibrated 5/8-inch diameter galvanized hollow pipe into the sediment until refusal. The depth of the penetrated sediment was noted by subtracting from the length of the entire rod, the length of the rod above the water surface, and the water depth at the point being probed. Using these methods, estimates of depth of sediment may be inaccurate.

Sediment sampling was then conducted at each probing point utilizing clear Lexan® tubing. Sections of the tubing were spliced together in areas of deep water or sediment. The tubing was hand pushed into the sediment and then driven utilizing a stainless steel core driver until refusal. A vacuum was then created within the tubing with a hand pump in order to keep the sediment in the tube during retrieval. The core tube, with the sample intact, was cut to size, capped, and labeled.

The sediment cores were described in logs, photographed, and placed into the BBL field office freezers to be preserved for possible future laboratory analyses.

A second sediment core sample was then obtained at each probing point using the procedures above to collect the upper four inches of sediment. The four-inch sample was extruded into a plastic 500-ml container, cataloged and retained in the BBL field office for possible future physical analyses.

At 42 transects (25 %), a water velocity reading was obtained at each probing point across the transect at a depth of 0.6 times the total water depth. The velocities were obtained at approximately every four to five transects or where field personnel noted a visually observable change in river velocity.

At each sediment probing point the following information was obtained and recorded:

- location;
- depth of sediment (refusal of probe);
- length of sediment recovered;
- depth of water;
- visual grain-size characterization (fine-grained or coarse-grained for the upper four inches);
- visual grain-size characterization (fine-grained or coarse-grained for the whole core);
- sediment descriptions (e.g., sediment composition, color, presence of debris, types of coarse material);
- water velocity at 0.6 times the total water depth (25 % of transects);
- River and Creek physical features; and
- other appropriate field conditions and observations.

Data from the sediment characterization study were used to estimate total volume of sediment in each of the 11 reaches, to map visually classified fine- vs. coarse-grained sediments, and to relate visually classified sediment grain-size to other physical variables (i.e. sediment depth, water velocity, water depth).

Ancillary data such as channel depth, velocity, and geometry were reviewed and related to depositional characteristics. This information may be used to assess subsequent sampling needs for estimating PCB concentrations and PCB mass within fine-grained and coarse-grained sediment in each reach.

The samples were collected in the manner prescribed in the Field Sampling Plan (FSP; Blasland & Bouck, 1993c), and Quality Assurance/Quality Control (QA/QC) samples were collected as described in the Quality Assurance Project Plan (QAPP; Blasland & Bouck, 1993b). Section 3.2.4 provides a summary of the QA/QC review.

Appendices A and G present the field data obtained at each sediment probing location. The River and the Creek cross-sections at each probing transect are presented in Appendix B. Field notes are provided as Appendix F.

2.2.1 Estimating Volume

Reach length, average sediment depth, and average water width measured during the SCS were used to estimate the total volume of instream sediments in each of the reaches. The total volume was estimated by: $V_{\text{total}} = (\text{reach length}) \times (\text{average water width}) \times (\text{average sediment depth})$. Because the methods used to estimate sediment depth were not standardized, these estimates of total sediment volume may be inaccurate and may be inconsistent among reaches.

The proportion of visually classified fine-grained sediment was estimated by: $(\text{number of fine-grained cores}) \div (\text{total number locations probed})$. The proportion of fine-grained sediments was also estimated using data from only those locations where a sediment core was collected; $P_{\text{fine}} = (\text{number of fine-grained cores among locations where a core was retained}) \div (\text{number of locations where a core was retained})$.

The volume of fine-grained sediment was then estimated by: $V_{\text{fine}} = P_{\text{fine}} \times V_{\text{total}}$. Sediments were visually classified as either fine- or coarse-grained based on dominant characteristics within the top four-inches of sediment and

alternatively, based on the dominant characteristics of the whole core. At locations where a sediment core was collected, the proportion and volume of fine- and coarse-grained sediments was calculated based on visual classification of the top four inches, as well as the whole core classification and the results were compared. The purpose of this comparison was to determine if classification of the top four inches of sediment could be used as a cost effective means to classify the proportion of fine- and coarse- grained sediments over an entire core. Volume of fine- and coarse-grained sediments reported in the results section are based on whole core classification of probing locations where a sediment core was collected because locations where cores were not collected were not visually classified consistently.

2.3 Results

2.3.1 Summary of Field Observations and Volume Estimates

Table 1 summarizes River and Creek reach lengths, average ground elevation slope, number of transects per mile, number of transects, number of probing points, and the number of velocity measurements. In total, 1,068 cores were collected from a total of 1,265 locations along 171 transects in the River and 15 transects in the Creek. Velocity was measured at 302 locations. A summary of the number of cores collected, average water depth, average river width, average sediment depth, and percent of cores visually classified as either fine- or coarse-grained for each reach is presented in Table 2. Differences in the number of probing locations (Table 1) and cores (Table 2) represent the number of locations from which no sediment core was recovered. Estimated volume of sediments are presented in Table 3. A summary of field observation and details of the probing and characterization activities are presented in Appendix A. The results of the SCS are summarized for each reach in the following paragraphs.

2.3.1.1 Reach A1: Morrow Lake Dam to Portage Creek Confluence

Reach A1 is 4.8 miles long containing 20 transects and 148 probing locations. The top four inches of sediments from all 148 probed locations were visually classified as fine- or coarse-grained. Sediment cores were recovered from 134 (91%) of 148 probed locations. Based on the top four inches, 32 (22%) out of 148 were visually classified as fine-grained. Where sediments were recovered, 31 (23%) out of 134 were visually classified as fine-grained. Also, where sediments were recovered, but based on whole core, 60 (45%) out of 134 were visually classified as fine-grained. The sampling intensity was 0.8 acres per core collected. Based on penetrated sediment the average depth was 3.2 feet (0.5 to 7.6 feet), and the average water depth was 3.0 feet (0.5 to 7.6 feet). Forty-five velocity measurements were taken in reach A1. Velocity measurements varied from 0.08 to 2.75 ft/sec, with an average of 1.5 ft/sec. The total estimated sediment volume was 556,000 yd³. Based on whole core characterization, 306,000 yd³ and 250,000 yd³ of sediment were visually classified as coarse- and fine-grained sediment, respectively.

2.3.1.2 Reach A2: Portage Creek Confluence to Main Street, Plainwell

Reach A2 is 16 miles long containing 35 transects and 245 probing locations. The top four inches of sediment from all 245 probed locations were visually classified as fine- or coarse-grained. Sediment cores were recovered from 206 (84%) out of 245 probed locations. Based on the top four inches, 60 (24%) out of 245 were visually classified as fine-grained. Where sediments were recovered, 58 (28%) out of 206 were visually classified as fine-grained. Also, where sediments were recovered, but based on whole core, 67 (33%) were visually classified as fine-grained. The sampling intensity was 1.7 acres per core collected. Based on penetrated sediment the average depth was 2.0 feet (0.1 to 6.7 feet), and the average water depth was 3.5 feet (0.6 to 10.7 feet). Sixty-eight velocity measurements were taken in reach A2. Water velocity varied from 0.05 to 3.5 ft/sec, with an average of 1.5 ft/sec. The total estimated sediment volume was 1,114,000 yd³. Based on whole core characterization, 746,000 yd³ and 368,000 yd³ of sediment were visually classified as coarse- and fine-grained sediment, respectively.

2.3.1.3 Reach B: Main Street, Plainwell to Plainwell Dam

Reach B is 2.1 mile long containing 13 transects and 92 probing locations. The top four inches of sediments from all 92 probed locations were visually classified as fine- or coarse-grained. Sediment cores were recovered from 67 (73%) out of 92 probed locations. Based on the top four inches, 47 (51%) out of 92 were visually classified as fine-grained. Where sediments were recovered, 45 (67%) out of 63 were visually classified as fine-grained. Also, where sediments were recovered, but based on whole core, 46 (69%) out of 67 were visually classified as fine-grained. The sampling intensity was 0.7 acres per core collected. Based on penetrated sediment the average depth was 1.8 feet (0.2 to 6.0 ft.), and the average water depth was 3.6 feet (0.7 to 8.0 ft.). Twenty-one velocity measurements were taken in reach B. Water velocity varied from 0.11 to 2.6 ft/sec, with an average of 1.6 ft/sec. The total estimated sediment volume was 146,000 yd³. Based on whole core characterization, 45,000 yd³ and 101,000 yd³ of sediment were visually classified as coarse- and fine-grained sediment, respectively.

2.3.1.4 Reach C: Plainwell Dam to Otsego City Dam

Reach C is 1.7 miles long containing 12 transects and 91 probing locations. The top four inches of sediment from all 91 probed locations were visually classified as fine- or coarse-grained. Sediment cores were recovered from 88 (97%) out of 91 probed locations. Based on the top four inches, 63 (69%) out of 91 were visually classified as fine-grained. Where sediments were recovered, 62 (70%) out of 88 were visually classified as fine-grained. Also, where sediments were recovered, but based on whole core, 80 (91%) out of 88 were visually classified as fine-grained. The sampling intensity was 1.0 acre per core collected. Based on penetrated sediment the average depth was 4.6 feet (0.5 to 8.5 feet), and the average water depth was 2.5 feet (0.3 to 7.0 feet). Twenty-eight velocity measurements were taken in reach C. Water velocity varied from 0.5 to 2.0 ft/sec, with an average of 1.3 ft/sec. The total estimated sediment volume was 682,000 yd³. Based on whole core characterization, 61,000 yd³ and 621,000 yd³ of sediment were visually classified as coarse- and fine-grained sediment, respectively.

2.3.1.5 Reach D: Otsego City Dam to Otsego Dam

Reach D is 3.3 miles long containing 14 transects and 95 probing locations. The top four inches of sediment from all 95 probed locations were visually classified as fine- or coarse-grained. Sediment cores were recovered from 63 (66%) out of 95 probed locations. Based on the top four inches, 38 (40%) out of 95 were visually classified as fine-grained. Where sediments were recovered, 36 (57%) out of 63 were visually classified as fine-grained. Also, where sediments were recovered, but based on whole core, 45 (71%) out of 63 were visually classified as fine-grained. The sampling intensity was 1.3 acres per core collected. Based on penetrated sediment the average depth was 3.4 feet (0.3 to 11.0 feet), and the average water depth was 3.7 feet (0.9 to 7.3 feet). Twenty-seven velocity measurements were taken in reach D. Water velocity varied from 0.2 to 4.5 ft/sec, with an average of 2.0 ft/sec. The total estimated sediment volume was 439,000 yd³. Based on whole core characterization, 127,000 yd³ and 312,000 yd³ of sediment were visually classified as coarse- and fine-grained sediment, respectively).

2.3.1.6 Reach E: Otsego Dam to Trowbridge Dam

Reach E is 4.0 miles long containing 15 transects and 103 probing locations. The top four inches of sediments from all 103 probed locations were visually classified as fine- or coarse-grained. Sediment cores were recovered from 78 (76%) out of 103 probed locations. Based on the top four inches, 59 (57%) out of 103 were visually classified as fine-grained. Where sediments were recovered, 59 (76%) out of 78 were visually classified as fine-grained. Also, where sediments were recovered, but based on whole core, 63 (81%) out of 78 were visually classified as fine-grained. The sampling intensity was 1.5 acres per core collected. Based on penetrated sediment the average depth was 3.4 feet (0.0 to 9.4 feet), and the average water depth was 5.0 feet (0.3 to 11.3 feet). Twenty-eight velocity measurements were taken in reach E. Water velocity varied from 0.1 to 3.9 ft/sec, with an average of 1.6 ft/sec. The total estimated sediment volume was 660,000 yd³. Based on whole core characterization, 125,000 yd³ and 535,000 yd³ of sediment were visually classified as coarse- and fine-grained sediment, respectively.

2.3.1.7 Reach F: Trowbridge Dam to Allegan City Line

Reach F is 6.9 miles long containing 16 transects and 107 probing locations. The top four inches of sediments from all 107 probed locations were visually classified as fine- or coarse-grained. Sediment cores were recovered from 66 (62%) out of 107 probed locations. Based on the top four inches, 32 (30%) out of 107 were visually classified as fine-grained. Where sediments were recovered, 32 (48%) out of 66 were visually classified as fine-grained. Also, where sediments were recovered, but based on whole core, 31 (47%) out of 66 were visually classified as fine-grained. The sampling intensity was 2.4 acres per core collected. Based on penetrated sediment the average depth was 2.2 feet (0.3 to 11.0 feet), and the average water depth was 4.4 feet (0.6 to 10.4 feet). Thirty-one velocity measurements were taken in reach F. Water velocity varied from 0.4 to 4.1 ft/sec., with an average of 2.2 ft/sec. The total estimated sediment volume was 570,000 yd³. Based on whole core characterization, 302,000 yd³ and 268,000 yd³ of sediment were visually classified as coarse- and fine-grained sediment, respectively.

2.3.1.8 Reach G: Allegan City Line to Allegan City Dam

Reach G is 1.8 miles long containing 15 transects and 116 probing locations. The top four inches of sediments from all 116 probed locations were visually classified as fine- or coarse-grained. Sediment cores were recovered from 113 (97%) out of 116 probed locations. Based on the top four inches, 96 (83%) out of 116 were visually classified as fine-grained. Where sediments were recovered, 96 (85%) out of 113 were visually classified as fine-grained. Also, where sediments were recovered, but based on whole core, 97 (86%) out of 113 were visually classified as fine-grained. The sampling intensity was 1.2 acres per core collected. Based on penetrated sediment the average depth was 5.9 feet (0.3 to 10.9 feet), and the average water depth was 3.7 feet (0.1 to 13.5 feet). Twenty-four velocity measurements were taken in reach G. Water velocity varied from 0.05 to 2.4 ft/sec., with an average of 1.1 ft/sec. The total estimated sediment volume was 1,329,000 yd³. Based on whole core characterization, 186,000 yd³ and 1,143,000 yd³ of sediment were visually classified as coarse- and fine-grained sediment, respectively.

2.3.1.9 Reach H: Allegan City Dam to Lake Allegan Dam

Reach H is 9.8 miles long containing 19 transects and 147 probing locations. The top four inches of sediments from all 147 probed locations were visually classified as fine- or coarse-grained. Sediment cores were recovered from 140 (95%) out of 147 probed locations. Based on the top four inches, 137 (93%) out of 147 were visually classified as fine-grained. Where sediments were recovered, 136 (97%) out of 140 were visually classified as fine-grained. Also, where sediments were recovered, but based on whole core, 135 (96%) out of 140 were visually classified as fine-grained. The sampling intensity was 14.2 acres per core collected. Based on penetrated sediment the average sediment depth was 7.9 feet (1.4 to 18.9 feet), and the average water depth was 7.0 feet (0.3 to 19.0 feet). Five velocity measurements were taken in reach H. Water velocity varied from 0.5 to 3.5 ft/sec., with an average of 2.6 ft/sec. The total estimated sediment volume was 25,284,000 yd³. Based on whole core characterization, 1,011,000 yd³ and 24,273,000 yd³ of sediment were visually classified as coarse- and fine-grained sediment, respectively.

2.3.1.10 Reach I: Lake Allegan Dam to 3.7 Miles Downstream of Lake Allegan Dam

Reach I is 3.7 miles long containing 12 transects and 72 probing locations. The top four inches of sediments from all 72 probed locations were visually classified as fine- or coarse-grained. Sediment cores were recovered from 71 (99%) out of 72 probed locations. Based on the top four inches, 43 (60%) out of 72 were visually classified as fine-grained. Where sediments were recovered, 43 (61%) out of 71 were visually classified as fine-grained. Also, where sediments were recovered, but based on whole core, 46 (65%) out of 71 were visually classified as fine-grained. The sampling intensity was 1.1 acres per core collected. Based on penetrated sediment the average depth was 5.2 feet (1.0 to 10.0 feet), and the average water depth was 6.8 feet (0.7 to 12.6 feet). Twelve velocity measurements were taken in reach I. Water velocity varied from 0.5 to 2.5 ft/sec., with an average of 1.3 ft/sec. The total estimated sediment volume was 640,000 yd³. Based on whole core characterization, 224,000 yd³ and 416,000 yd³ of sediment were visually classified as coarse- and fine-grained sediment, respectively.

2.3.1.11 Reach P: Portage Creek , Alcott Street to Confluence with Kalamazoo River

Reach P is 2.0 miles long containing 15 transects and 49 probing locations. The top four inches of sediments from all 49 probed locations were visually classified as fine- or coarse-grained. Sediment cores were recovered from 42 (86%) out of 49 probed locations. Based on the top four inches, 25 (51%) out of 49 were visually classified as fine-grained. Where sediments were recovered, 24 (57%) out of 42 were visually classified as fine-grained. Also, where sediments were recovered, but based on whole core, 24 (57%) out of 42 were visually classified as fine-grained. The sampling intensity was 0.2 acres per core collected. Based on penetrated sediment the average sediment depth was 4.2 feet (0.4 to 8.8 feet), and the average water depth was 2.0 feet (0.4 to 7.6 feet). Thirteen velocity measurements were taken in reach P. Water velocity varied from 0.15 to 2.3 ft/sec., with an average of 1.3 ft/sec. The total estimated sediment volume was 52,000 yd³. Based on whole core characterization, 22,000 yd³ and 30,000 yd³ of sediment were visually classified as coarse- and fine-grained sediment, respectively.

River reaches C (Plainwell Dam to Otsego City Dam), G (Allegan City Line to Allegan City Dam) and H (Allegan City Dam to Lake Allegan Dam) have the highest percentage of cores classified as fine-grained sediments. Reaches A1 and A2 (Morrow Lake Dam to Main Street, Plainwell) have the lowest percentage of fine-grained sediments. The spatial distribution of visually classified fine- and coarse-grained sediment classifications is shown in Figures 2 through 9. The percentage of cores classified as fine-grained within each River reach is shown in Figure 10, and the estimated volume associated with sediments classified as fine- or coarse-grained is shown in Figure 11 and summarized in Table 3.

The classification of the upper four inches and the whole core agreed in 89 % of the cases. There were 25 cases (2 %) where fine-grained material was present at the surface while the whole core was classified as predominantly coarse material. In 97 cases (8 %) the upper four inches were classified as coarse, while the whole core was classified as fine. Of these 97 cases 45 occur in reaches A1 (upstream of the confluence with Portage Creek) and A2 (Portage Creek Confluence to Main Street Plainwell), 30 and 15 respectively. Another area of coarse material overlying fine-grain sediment occurs in the area of sandbars downstream of Plainwell Dam. These sandbars may reduce the cross sectional area available to convey River flow, increasing local velocity. Coarse material overlying fine-grain sediment is also observed at several locations in the upper portions of the Otsego and Trowbridge former impoundments.

The occurrence of fine-grained sediment overlying coarse-grained sediment was scattered, although they appear more frequently associated with the near-shore environment rather than mid-channel locations.

2.3.2 Relationship of Fine-Grained Sediment Deposition to Other Observed Characteristics

2.3.2.1 Relationship to Velocity

It was expected that the deposition of fine-grained sediments would occur in low energy (low velocity) zones of the River. Sediment classifications from probing locations where velocity measurements were obtained show a decrease in the occurrence of fine-grained sediment with increasing stream velocity (Figure 12). At locations where measured velocity was less than 0.5 ft/sec., nearly 80 percent of the cores were classified as fine-grained. Where velocities were greater than 3 ft/sec., 13 percent of the cores were classified as fine-grained. Because the velocity is related to the River discharge, which varied during the probing activity, direct comparison of velocities is inappropriate, yet the general pattern of the results substantiate the increased occurrence of fine-grained sediments with decreasing velocity.

2.3.2.2 Relationship to Channel Characteristics

Each probing location was categorized as being located in a former impoundment, a current impoundment, or from a free-flowing portion of the River. The former impoundments include Plainwell Impoundment (transects KPT-60 to KPT-67), Otsego Impoundment (transects KPT-85 to KPT-94), and Trowbridge Impoundment (transects KPT-95 to KPT-109). These impoundments were previously removed to their sill elevation. Current impoundments include Otsego City Impoundment (transects KPT-68 to KPT-79), Allegan City Dam Impoundment (transects KPT-129 to KPT-139) and Lake Allegan (transects KPT-145 to KPT-159). The remaining transects (KPT-1 through -59, -80 through -84, -110 through -128, -140 through -143, and -160 through -171) were collected from reaches of the River classified as free-flowing. Transect KPT-144 was not collected. The percentage of cores classified, as fine-grained sediments were determined for the former impoundments, current impoundments, and free-flowing reaches of the River. Results indicate that fine-grained sediments are most frequently identified in current impoundments and least frequently identified in the free-flowing reaches of the River (Figure 13).

Each probing location was also designated as being either a mid-channel or near-shore location. Sediments from near-shore locations were more frequently classified as fine-grained than were mid-channel locations (67 % versus 40 % for the upper four inches). The difference between near-shore and mid-channel locations was greatest in free-flowing reaches of the River (54 % versus 20 %). The increased frequency of fine-grained sediments identified within current impoundments and near-shore is consistent with the deposition of fine-grained sediments in low-energy zones of the River.

2.3.2.3 Relationship to Sediment Thickness

Accumulated thickness of sediments was expected to be greatest in the low-energy depositional areas. The relationship between velocity and average sediment thickness is shown in Figure 14. Based on the method used to measure sediment thickness during the SCS, the average thickness of sediment deposits classified as fine-grained was 5.4 feet, whereas coarse-grained sediment thickness averaged 2.1 feet.

The relationship between sediment thickness and channel characteristics is shown in Figure 15; sediment deposits average 6.7 feet in current impoundments, compared to 2.6 feet in free-flowing reaches of the River.

2.4 Preliminary Findings

2.4.1 Applicability of Stratified Sampling Approach

In general, relationships identified in field data collected during the SCS support the principle that the greatest deposition of fine-grained sediment is found in low-energy zones. For example, fine-grained sediments are found more frequently and in greater volume (thickness) within the current impoundments, which are generally low-velocity areas of the River. Within the free-flowing reaches of the River, fine-grained sediments are more likely to be found near-shore, rather than in mid-channel. The field data also indicate that fine-grained deposits are thicker than those classified as coarse.

It may be possible to identify locations in the River that most likely have substantial deposits of fine-grained sediments. Pending the PCB analytical results of sediment cores from each reach of the River, the merits of a stratified sampling approach can be evaluated for each reach.

The surficial sediment classification scheme (top four inches of sediment) did not agree well with the whole core classification scheme in reaches A1 and A2. In general, the surficial classification scheme agreed most strongly with the whole core classification scheme when the proportion of fine-grained sediment cores was highest, such as in the current impoundments. A plausible interpretation is that surficial and deeper sediments are more similar in areas where velocities are consistently maintained at lower levels. Conversely, free flowing reaches where flow regimes may be more variable, may result in situations where the characteristics of the top four inches of sediment differ from characteristics of deeper sediments.

3.0 Geostatistical Pilot Study

3.1 *Rationale*

Geostatistics are statistical methods that incorporate spatial dependencies among data. For example, if PCB concentration were independently distributed, knowledge of PCB concentration at one location would not provide information about PCB concentration at a nearby location. When data are spatially auto-correlated (i.e. self-related) knowledge of PCB concentration at one location may provide information about nearby locations. Geostatistical methods use a function called the variogram to describe this spatial relationship. Geostatistical analyses may include mapping the variables of interest (e.g. grain-size and PCB concentration) or more conventional analyses such as regression or analysis of variance. Mapping usually entails a spatial averaging method known as kriging. Kriging is a linear weighted-averaging technique used to estimate a variable of interest (i.e., PCB concentration) at un-sampled locations based on PCB concentration measurements at other locations. Additional analyses are generalizations of standard statistical methods that incorporate spatial correlation into the analysis. For example, estimation of the mean when data are spatially correlated would be based on a spatially weighted average as opposed to the usual arithmetic average. The spatial weights are determined by the estimated variogram. The purpose of the geostatistical pilot study was to evaluate the spatial correlation among samples in a one-mile reach of the River, and to construct contour maps of the spatial distribution of geometric mean PCB concentration within that reach of the River.

Geostatistical studies frequently use a multiphase approach, with the first sampling phase being oriented primarily towards estimating the sample variogram. The GPS was composed of only the first phase, designed primarily for variogram estimation. Because the variogram plays an essential role in subsequent geostatistically-based procedures, such as sampling network design or mapping results, special attention is given to the initial phase of a geostatistical study. The variogram describes the variability at very close distances (nugget), the variability when samples are distant and considered statistically independent (sill), and the distance at which two samples can be considered statistically independent (the range of correlation). A spatial process is said to be anisotropic when the range of correlation varies with direction. It is anticipated that depositional patterns in the River will vary with direction. For example, PCB concentration can be expected to be less variable along the direction of river flow than across the direction of flow. This anisotropy was investigated with the pilot study data by estimating a variogram along river flow and across river flow.

For mapping PCB concentration, the secondary sampling phase of a typical geostatistical study would cover a larger area with sufficient sample points to contour the data within an acceptable error of interpolation (Flatman et al., 1988). Data from the GPS could also be used to investigate sampling requirements for estimating geometric mean PCB concentration at varying spatial scales. However, such investigations are beyond the scope of this technical memorandum.

Typically, PCB adheres to organic carbon-containing particles, and may be associated with lower flow velocities and sediment depositional areas within the River. One hypothesis is that the highest PCB concentrations (as well as other hydrophobic constituents) may be found in sediments in low-energy zones within the River and Creek, where fine-grained sediments accumulate. PCB data from the GPS were used to test this hypothesis, although inferences are restricted to the one-mile long GPS area.

PCB analyses from the GPS are used to evaluate associations between PCB concentration and physical characteristics. Additionally, data from the SCS may be used with subsequent PCB analyses to investigate the merits of Hakanson's approach on the River or Creek. It is anticipated that associations between PCB concentration and physical characteristics may vary between former impoundments, current impoundments, and free-flowing reaches of the River. In addition, the associations may also vary with proximity to known historic point source discharges. For these reasons, direct application of associations found in the GPS may not be appropriate in other River reaches. Extrapolation of results of this un-replicated study to other areas outside the one-mile study region would be considered a form of pseudoreplication (Hurlbert 1984).

3.2 Investigation Activities

3.2.1 Field Activities

A one-mile reach of the River upstream of the former Trowbridge Dam was selected as the site for the GPS. This reach was selected because it contains one straight and one meandering section of the River. Each sample location was marked on an aerial photograph of the GPS area (Figure 16). Based on aerial photographs and surveyor notes, each sample location was converted to an X-Y coordinate system. The X coordinate was the distance upstream of transect KPT-100, whereas the Y coordinate was the location of the sampling point, expressed as a percent of the total width from the right edge (looking upstream) of water. In effect, this created a coordinate system representing the longitudinal (X) and lateral (Y) axes of the river.

Sixty-two sediment cores were collected in the GPS area on October 12 through October 14, 1993 (Figure 16). The goal of the sampling was to obtain a core passing through PCB-containing sediment. A minimum core depth of three feet was an objective. However, three feet or more of sediment was recovered at only four locations (KPS-46, KPS-49, KPS-57, and KPS-62) close to shore. No sediment was recovered at four other locations (KPS-40, KPS-43, KPS-55, and KPS-61) in mid-channel.

At each sampling location, the depth of water was measured by probing with a surveyor's rod. The depth of sediment was then measured by pushing a calibrated 5/8-inch galvanized hollow pipe into the sediment until refusal. The depth of the penetrated sediment was noted by subtracting from the length of the entire rod, the length of the rod above the water surface, and the water depth at the point being probed.

Sediment sampling was then conducted at each probing point utilizing clear Lexan® tubing. Sections of the tubing were spliced together in areas of deep water and/or sediment. The tubing was hand pushed into the sediment and then driven utilizing a stainless steel core driver until refusal. A vacuum was then created within the tubing with a hand pump in order to keep the sediment in the tube during retrieval. The core tube, with the sample intact, was cut to size, capped, and labeled.

Where possible, two samples were collected from each core. The upper one-foot interval and lowest one-foot interval above any visually identifiable gray clay/non-cohesive sediment interface of each core were sent for PCB analysis. If no interface was visually identifiable, samples were collected from the top one-foot of the core as well as from the bottom one-foot interval. If less than one foot of sediment was recovered, the entire core was sent for PCB analysis. Core sections were placed in bottles for shipment to the laboratory.

Water depth, depth of sediment penetrated, sediment recovery, and lithologic descriptions were noted for all cores. In addition, each core was photographed. Field notes obtained during the GPS sampling activities are presented in Appendix F.

The samples were collected in the manner prescribed in the FSP (Blasland & Bouck, 1993c), and QA/QC samples were collected according to the methods presented in the QAPP (Blasland & Bouck, 1993b). Section 3.2.4 provides a brief summary of the QA/QC review.

3.2.2 Analytical Data Summary

PCB analytical data are summarized in tabular form in Tables 4 and 5. The summaries include estimates of minimum and maximum concentration, proportion of detectable concentrations, geometric mean, robust log probability mean, and approximate confidence limits for the geometric mean for fine- and coarse-grained sediments (Table 4) and for river shape characteristics (Table 5). The PCB analytical data contain a large proportion of observations that are below levels of detection (0.056 mg/kg to 0.17 mg/kg); therefore, geometric mean PCB concentration and mean concentration were estimated using the methods described below.

Each sample collected during the GPS was classified as fine- or coarse-grained sediment similar to the visual classification method used during the SCS. Mean PCB concentration was estimated using Robust Log-Probability Regression (Helsel, 1990).

Geometric mean PCB concentration was estimated for fine- and coarse-grained sediments and for both combined. Before calculating the geometric mean, less-than detects were replaced with one half the reported detection limits. This procedure is unbiased for estimating the mean provided all values of PCB concentration below detection limits are equally likely (Gilbert, 1987, p. 178). However, this procedure is not unbiased for estimating the variance, so to improve estimation of the variance, the sample variance of log transformed data was calculated by first replacing less than detects with a uniformly distributed random number between zero and the reported level of detection. The geometric mean is an estimator of the median of the distribution. The sample median (50 %) could not be estimated because more than half the observed data were either less than levels of detection or estimated concentrations that were less than the maximum detection limit.

Minimum, maximum, geometric mean and approximate 95 percent confidence limits were calculated for PCB concentration for each subset of the data classified by sample position in the River (inside bend, outside bend, mid-channel of bend or straight reach). Less-than detects were replaced by uniformly distributed random numbers to estimate the variance.

3.2.3 Point Kriging and Mapping

PCB concentration data from the zero- to one-foot sampling interval from 58 locations were used in the geostatistical analysis. Because only 16 samples were recovered from below the one-foot depth, there is insufficient information to perform a geostatistical analysis on the individual layers (upper one-foot and lower one-foot). Consequently, further analyses were conducted on PCB analytical data from only the upper one-foot of sediment. These sediments are herein referred to as "surficial."

PCB concentrations were base ten log transformed to improve the symmetry of the distribution. Of 58 observations, 20 (34%) had PCB concentrations that were below detection limits. One-half the minimum detection limit was used for samples with non-detectable PCB concentrations for contour mapping. The variogram was estimated with the less-than detects replaced by random uniform numbers between zero and the detection limits. This latter approach would be expected to overestimate the sill and nugget effect thereby precluding underestimation of sample size requirements. This is a conservative approach for design of sampling plans.

The sampling effort required to develop contour maps within the one-mile GPS area, with optimal precision, was evaluated in accordance with the recommendation for sample network design given in Flatman, et al. (1988). Variograms and contour maps were estimated from the PCB data collected during the GPS using GeoEAS software (Englund and Sparks, 1988).

3.2.4 QA/QC Review of Data

Analytical data reports for the GPS sediment samples underwent detailed review and evaluation to assess overall analytical precision and accuracy. Analytical data, organized into five sample delivery groups (SDGs), were reviewed using techniques appropriate to the various media and compounds tested. The SDGs are designated as 40088, 40090, 40144, 40145, and 40146. Table 6 presents the SDGs and their associated samples.

Laboratory analytical precision was assessed by comparing the results between the matrix spike and matrix spike duplicate samples. Field duplicate samples were also used to assess overall precision of the laboratory analysis. The relative percent differences (RPD) were calculated for each pair of duplicate analyses. The RPD calculations for field duplicates were based on total PCB content.

Matrix spike recoveries and other indicators of accuracy, such as surrogate and blank spike recovery data, were examined to assess the accuracy of the analytical method.

A precision and accuracy summary as determined in the review of all Sample Delivery Groups is presented in Appendix C.

A more detailed analysis of data quality can be found in the data review reports presented in Appendix D. Also note that data review procedures derive from applicable USEPA Guidance (USEPA, 1991a; 1991b; and 1991c) and the QAPP (Blasland & Bouck Engineers, 1993b).

Chain-of-Custody records are presented in Appendix E.

3.3 Results

3.3.1 Summary of Field Observations

Sample locations were identified on 1:2400 scale aerial photographs. Figure 16 depicts the sample locations. A total of 74 samples were obtained from 58 (of the 62 originally designated) core locations within the GPS area. At four locations (KPS-40, KPS-43, KPS-55, and KPS-61) no core was recovered. Each of the designated sample locations where there was no core recovered was a mid-channel location. At 16 locations, samples from either the deepest one-foot of the core or the one-foot reach above a visually identifiable gray clay/non-cohesive sediment interface were obtained. Deeper samples were not obtained from cores collected at the other 42 locations because the average sediment thickness at those locations was only 1.2 feet, compared to an average thickness of 3.4 feet where samples were obtained from two depths.

Cores were classified as being from either straight or bending (meanders) sections of the River. Cores from bending sections were further classified as being from the inside, mid-channel, or outside of the bend. Average sediment depth was greatest (3.3 feet) for the 16 samples collected from an inside bend. Sediment deposits were not as thick for those cores collected from straight sections of the River (1.7 feet) or from mid-channel of bends (1.5 feet). Average sediment thickness for 11 cores collected from the outside of a bend is 2.2 feet.

Table 7 presents the field observations made at each core location, including water depth, sediment penetration depth, sediment recovery, visual description of the sediment, and the top and bottom depth of samples. Observed water depth ranged between 0.8 and 7.5 feet, with an average of 2.8 feet. Sediment thickness based on the penetration, ranges from 0.5 to 7.2 feet, with an average of 2.2 feet. The average thickness of recovered sediment is 1.3 feet. Sediment recovery averaged 59% (average thickness recovered ÷ average thickness penetrated).

There are 38 (66%) cores visually classified as coarse-grained and 20 (34%) cores visually classified as fine-grained. For comparison, 633 (50%) and 632 (50%) of the SCS cores are visually classified as coarse- and fine-grained, respectively.

3.3.2 PCB Analytical Results

PCB analytical results are presented in Table 8 and Figure 17. Detectable PCB concentrations were recorded in 41 of the 74 samples, ranging from 0.024 mg/kg (estimated) to 7.8 mg/kg. PCB concentrations in the remaining 33 samples (45 %) were reported as below detection limits, ranging from 0.055 to 0.17 mg/kg. The PCB concentration frequency distribution is presented in Figure 18.

Figures 19 to 21 depict PCB concentration and sediment depths for three cross-sections of the GPS area, where five or more sampling locations were established. The maximum PCB concentration reported for each cross-section is 0.48 mg/kg for the upstream-most cross-section (Figure 19); 3.6 mg/kg for the middle cross-section (Figure 20); and, 6.1 mg/kg for the downstream-most cross-section (Figure 21). All three cross-sections contain samples with PCB analytical results reported as below detection limits.

PCB concentration was greater in the deeper sediment sample at only one of the 16 locations where two samples were collected and analyzed from a core. This occurred at sample location KPS-45, where PCB concentration was reported as 4.0 mg/kg in the zero to one-foot sample, and at 5.4 mg/kg in the deeper sample, respectively.

Twenty of 58 (35%) surficial sediment samples had PCB concentrations that were less than detection limits. Of 33 samples classified as fine-grained, 21 (64%) had reported concentration less than the maximum detection limit among fine-grained sediments (0.170 mg/kg). Therefore, the sample median sediment concentration could not be estimated for fine-grained sediments and estimates of the average or geometric mean concentration should be interpreted cautiously.

Of 41 sediment samples classified as coarse-grained, 27 (66%) had reported PCB concentrations below the maximum detection limit among coarse-grained sediment samples (0.071 mg/kg). As with the fine-grained samples, the median sediment concentration could not be estimated for coarse-grained sediments and quantification of the average concentration should be interpreted cautiously.

Robust Log-Probability Regression (Helsel, 1990) was used to estimate mean PCB concentration in the GPS area. The estimated mean PCB concentration for all samples is 0.54 mg/kg. The mean concentration for fine-grained sediment is 0.95 mg/kg, whereas the mean concentration for coarse-grained sediments is 0.22 mg/kg. Helsel (1990) points out the rationale for not evaluating the statistical difference of means in data sets that have a high proportion of non-detects; therefore, the statistical significance of the difference in means was not compared because of the high proportion of non-detects.

Although the proportion of samples that were below detection was high, geometric mean PCB concentrations were compared; however, this comparison may not be reliable, and inferences should be made cautiously. Because the geometric mean concentrations were close to the detection limits, the sample variance and mean estimates may have been adversely affected by the detection limits. Geometric mean PCB concentration was higher ($p=0.024$) in fine-grained sediments (0.26 mg/kg) than in coarse-grained sediments (0.08 mg/kg). This difference supports the hypothesis that PCB mass is preferentially associated with fine-grained sediments. The PCB data are summarized in Table 4.

Geometric mean PCB concentration was estimated for samples that were located on inside bends, outside bends, mid-channel of bends and in straight reaches of the River. The geometric means ranged from 0.06 mg/kg in straight reaches to 0.64 mg/kg on inside bends. The geometric means and approximate confidence limits are summarized in Table 5 and Figure 22. The confidence limits are approximate due to the high proportion of below detects in the data.

As an alternative to direct comparison of means and medians, the proportion of all fine-grained samples with detectable PCB concentrations was compared to the proportion of all coarse-grained samples with detectable concentrations. The proportion of coarse-grained sediment samples with detectable PCB concentrations ($26/41=63\%$) was higher ($\chi^2 = 1.7$, $p=0.19$) than the proportion of fine-grained sediment samples with detectable PCB concentrations ($15/33=45\%$). This positive association between coarse-grained samples and proportion of samples with detectable PCB concentrations does not support the hypothesis that PCBs are associated with fine-grained sediments.

3.3.3 Variogram Analysis and Kriging

For the lateral axis (across the river), 163 pairs of data were used to develop the variogram. The best-fit variogram for the lateral direction was a spherical model with a nugget of $0.35 \log_{10}(\text{mg/kg})^2$, sill of $0.75 \log_{10}(\text{mg/kg})^2$, and lateral range of correlation of 110%. The range can be greater than 100% of stream width due to tolerance angles used in selection of data pairs. One observation made while developing the lateral variogram was that as the distance between data pairs approached 100 %, the variability between pairs decreased. This is likely an indication that sample pairs in the same cross-section located on opposite sides of the river are more similar to each other than they are to samples from mid-channel.

For the longitudinal direction (upstream/downstream), a spherical model with a $0.3 \log_{10}(\text{mg/kg})^2$ nugget, $0.7 \log_{10}(\text{mg/kg})^2$ sill, and 400-foot longitudinal range of correlation best fit the data. Beyond the range of correlation, samples are assumed to be independent.

Anisotropy in the variograms was represented in the kriging algorithm by a radial variogram with an elliptical base with major axis (longitudinal) of 400 feet, and minor axis (lateral) of 100%. The nugget was set to $0.3 \log_{10}(\text{mg/kg})^2$ and sill to $0.7 \log_{10}(\text{mg/kg})^2$. The kriging procedure was used to estimate the geometric mean PCB concentration at 600 points on a 200 foot (upstream/downstream) by 5 % (cross-stream direction) interval grid used to represent the GPS area. In general, the arithmetic mean can be expected to be greater than the geometric mean when data are positively skewed, as were the data from this one-mile pilot study area. The predicted geometric mean values were contoured, and approximate contours were transferred by hand to an aerial photograph of the pilot study area (Figure 23). The results do support the hypothesis of higher PCB concentration toward the banks as opposed to mid-channel, and higher concentrations in bends of the River, compared to straight sections. PCB concentration also tends to increase with distance downstream within this one-mile reach.

The standard error associated with each predicted PCB concentration was estimated in log transformed units. This estimated error is a function of the variogram used and density of sampled points, and is not affected by the PCB values at these sampled points. The standard error associated with the log transformed concentration estimates generally range from 0.4 to 0.6. The denser the sampling locations, the lower the associated error. The upper and lower approximate 67% confidence limits for geometric mean PCB concentration (based on geometric mean plus or minus one standard error) are shown in Figures 24 and 25, respectively. The directional semi-variograms are plotted in Figures 26 and 27.

3.4 Preliminary Findings

3.4.1 Relationship Between PCB Concentration and Physical Characteristics

In the statistical literature, less than detects are referred to as censored observations. As Helsel (1990) put it; *'When severe censoring (near 50% or more) occurs, ... The investigator will find it difficult to state conclusions about the relative magnitudes of central values and other characteristics must be compared.'* In spite of this, the geometric mean PCB concentrations in fine- and coarse-grained sediments were estimated and compared using a two-sample t-test. For this comparison, the sample variances were estimated using uniformly distributed random numbers in place of less than detects. This approach should have tended to over-estimate the variance making the t-test conservative.

Samples were classified according to position in the river and river shape. Geometric mean PCB concentration for samples from inside bends were over four times greater than the geometric mean for samples collected on outside bends and 10 times greater than the geometric mean concentration for samples collected in straight reaches. This result cannot be extrapolated to the River at large, but this relationship should be further explored with additional PCB analytical data from samples collected in the probing study. Additionally, the sampling design for the SCS should be investigated further regarding representation of river bends.

The association between PCB concentration and physical characteristics of the river was not definitive. The four highest PCB concentrations (3.9 to 7.8 mg/kg) observed in the GPS data were in sediments classified as fine, although the fifth highest concentration (3.6 mg/kg) was classified as coarse-grained. Due to the high proportion of observations below detection limits, average and median concentrations could not be reliably compared (Helsel, 1990). Coarse-grained surficial sediments contained the highest proportion (65% vs. 45%) of detectable PCB concentrations, although the probability of observing a difference of this magnitude by chance alone was 20%.

Based on these conflicting results, the PCB observations from the GPS provide inconclusive evidence regarding the reliability of associations between PCB concentration and therefore the applicability of stratified sampling plans. It is not known whether this lack of a clear association between PCB concentration and sediment grain size is due to the specific conditions along the one-mile GPS area or rather that the association is weak in general due to some subtle environmental chemistry phenomenon. These data do not strongly support application of stratified sampling

designs. Additional investigations of data representing a wider range of PCB concentrations may help to clarify this relationship.

Associations between PCB concentration and physical characteristics of the River may be complex varying with sediment depth, river geometry and water velocity, proximity to point source discharges, and river reach, among other factors. Regression or logistic regression (Helsel, 1990) techniques could be used to evaluate these multivariate associations between PCB concentration and other physical characteristics. Although this more sophisticated statistical analysis is beyond the scope of the technical memorandum, this approach should be investigated using the GPS and any other PCB data which may become available in the future.

3.4.2 Geostatistical Analysis

The cost effectiveness of sampling for development of contour maps increases with the strength of spatial correlation. PCB concentrations obtained from the GPS area vary significantly at relatively small spatial separation, with over 30% of the total variation accounted for by nugget effect (e.g., error that cannot be explained by the variogram). The high degree of variability is evident in the PCB data (Table 8 and Figure 18) and within the three cross-sections (Figures 19, 20, and 21). It is also evident in the parameters used to define the variogram developed as part of the geostatistical analysis, specifically the ratio of the nugget-to-sill value, and the relatively short range of correlation relative to the length of the River. This high degree of variation between sample data collected in close proximity is an indication that sampling grids used to characterize local scale patterns in PCB deposition must be dense.

The ratio of the nugget to sill was used to determine the optimum distance between sampling points that would yield minimum estimation variance while not over-sampling. Based on the relationship between the nugget to-sill-ratio and sampling distance presented in Flatman et al. (1988), a grid spacing of one third the range of correlation appears optimal. With a longitudinal range of correlation of 400 feet, transects every 125 to 150 feet would be close to optimal. For river reach E, where the GPS was performed, approximately 35 transects and 105 core locations would be required per mile to optimize the sampling design for development of contour maps. Because the GPS was conducted on only a single one-mile reach of the River, these results cannot be extrapolated to infer sampling requirements in other River reaches.

Given these results, one might conclude that development of highly precise contour maps may be prohibitively expensive. On the other hand, some remedial decisions may not require highly precise estimates. For example, in the kriging pilot study area where PCB concentrations are predominantly at low levels, moderate sampling intensities may be used to make remedial decisions. Suppose that a cleanup threshold of 0.12 mg/kg for the geometric mean were agreed upon. Based on Figure 24, the kriged estimates developed for this report could be used to argue that geometric mean concentrations in areas colored blue or gray and some areas colored yellow (much of this reach) are below the hypothetical cleanup standard with 84% level of confidence. This level of decision making was obtained with 58 locations per mile or a total of 3248 samples for the area from Morrow Dam downstream to below Calkins Dam. It should be noted that these 58 samples were not optimally located for developing the kriged map, so further reduction in costs could be attained by utilizing a more efficient, regularly spaced grid design.

In addition to refining the grid design, it is possible that the entire River may not need to be contoured in order to make remedial decisions. One plausible approach would be to utilize an initial non-intensive sampling design to estimate average concentration over reach or large sub-reach scales. Once areas with obviously low average concentrations are identified, additional resources could be expended to increase sampling intensity in those areas to demonstrate with contour maps that concentrations are below remedial action limits. This would not require intensive sampling of the entire River.

Those reaches where reach-wide average concentration is clearly above action limits would not need additional sampling unless there was some indication that localized patches might be below cleanup standards. Detailed high-intensity sampling would only be necessary in areas where concentrations are near action limits and remedial actions are in question.

The variogram and geostatistical analysis discussed above focused on the objective of prediction at unsampled point locations. While this is useful for development of contour maps, this analysis may be at a finer scale than is required for remedial action decisions.

In this report, associations between physical river and sediment characteristics and sediment PCB concentrations were evaluated. The GPS did not include any of this information in development of estimates of PCB concentration at un-sampled locations. Incorporation of more complex multivariate associations into the geostatistical analysis may also improve the precision of estimates. Further investigations should incorporate physical river characteristics into the geostatistical analysis using universal or co-kriging methods or logistic regression analysis.

4.0 REFERENCES

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TABLE 1

**ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
SEDIMENT CHARACTERIZATION AND GEOSTATISTICAL PILOT STUDY**

RIVER REACH CHARACTERISTICS AND PROBING SUMMARY

River Reach	Reach Length (miles)	Reach Slope (ft/mile)	Number of Transects	Transects per Mile	Number of Probing Points	Number of Velocity Measurements
A1. Morrow Lake Dam to Portage Creek Confluence	4.8	2.9	20	4.2	148	45
A2. Portage Creek Confluence to Main Street, Plainwell	16	2.8	35	2.2	245	68
B. Main Street, Plainwell to Plainwell Dam	2.1	5.8	13	6.2	92	21
C. Plainwell Dam to Otsego City Dam	1.7	2.2	12	7.1	91	28
D. Otsego City Dam to Otsego Dam	3.3	2.9	14	4.2	95	27
E. Otsego Dam to Trowbridge Dam	4.0	1.4	15	3.8	103	28
F. Trowbridge Dam to Allegan City Line	6.9	3.4	16	2.3	107	31
G. Allegan City Line to Allegan City Dam	1.8	1.0	15	8.3	116	24
H. Allegan City Dam to Lake Allegan Dam	9.8	1.1	19	1.9	147	5
I. Lake Allegan Dam to 3.7 miles downstream of Lake Allegan Dam	3.7	1.1	12	3.2	72	12
P. Portage Creek - Alcott Street to Confluence	2.03	1.9	15	7.4	49	13
Totals	56	--	186	3.3	1265	302

TABLE 2

**ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
SEDIMENT CHARACTERIZATION AND GEOSTATISTICAL PILOT STUDY**

SUMMARY OF OBSERVED FIELD MEASUREMENTS BY RIVER REACHES

River Reach	Number of Cores Collected ¹	Average Water Depth (feet)	Average River Width ² (feet)	Area (Acres)	Acres per Core	Average Sediment Depth (feet)	Percent Fine (top 4 inches) ^{3,4}	Percent Fine (top 4 inches) /(Whole Core) ^{4,5}
A1. Morrow Lake Dam to Portage Creek Confluence	134	3.0	185	108	0.8	3.2	22	23 / 45
A2. Portage Creek Confluence to Main Street, Plainwell	206	3.5	178	345	1.7	2.0	24	28 / 33
B. Main Street, Plainwell to Plainwell Dam	67	3.6	197	48	0.7	1.8	51	67 / 69
C. Plainwell Dam to Otsego City Dam	88	2.5	446	92	1.0	4.6	69	70 / 91
D. Otsego City Dam to Otsego Dam	63	3.7	200	80	1.3	3.4	40	57 / 71
E. Otsego Dam to Trowbridge Dam	78	5.0	248	120	1.5	3.4	57	76 / 81
F. Trowbridge Dam to Allegan City Line	66	4.4	192	161	2.4	2.2	30	48 / 47
G. Allegan City Line to Allegan City Dam	113	3.7	640	140	1.2	5.9	83	85 / 86
H. Allegan City Dam to Lake Allegan Dam	140	7.0	1670	1984	14.2	7.9	93	97 / 96
I. Lake Allegan Dam to 3.7 miles downstream of Lake Allegan Dam	71	6.8	170	76	1.1	5.2	60	61 / 65
P. Portage Creek	42	2.0	31	8	0.2	4.2	51	57 / 57
Totals	1068	--	--	3162	3.0	--	--	--

Notes:

- 1 Data for Transect KPT-144 has not been collected to date.
- 2 Average widths represent the actual water widths for the respective transects excluding islands or sandbars.
- 3 Based on all locations probed.
- 4 Classification was based on a qualitative visual scheme. Classification of no-core locations may not be accurate.
- 5 Based on locations where a core was collected.

TABLE 3

**ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
SEDIMENT CHARACTERIZATION AND GEOSTATISTICAL PILOT STUDY**

ESTIMATED VOLUME OF SEDIMENTS

River Reach	Volume of Fine Sediment ^{1,2} (cu yd)		Volume of Coarse Sediment ^{1,2} (cu yd)	
	Based on Upper 4-Inch Characterization	Based on Whole Core Characterization	Based on Upper 4-Inch Characterization	Based on Whole Core Characterization
A1. Morrow Lake Dam to Portage Creek Confluence	128,000	250,000	428,000	306,000
A2. Portage Creek Confluence to Main Street, Plainwell	312,000	368,000	802,000	746,000
B. Main Street, Plainwell to Plainwell Dam	98,000	101,000	48,000	45,000
C. Plainwell Dam to Otsego City Dam	477,000	621,000	205,000	61,000
D. Otsego City Dam to Otsego Dam	250,000	312,000	189,000	127,000
E. Otsego Dam to Trowbridge Dam	502,000	535,000	158,000	125,000
F. Trowbridge Dam to Allegan City Line	274,000	268,000	296,000	302,000
G. Allegan City Line to Allegan City Dam	1,130,000	1,143,000	199,000	186,000
H. Allegan City Dam to Lake Allegan Dam	24,525,000	24,273,000	759,000	1,011,000
I. Lake Allegan Dam to 3.7 miles downstream of Lake Allegan Dam	390,000	416,000	250,000	224,000
P. Portage Creek	30,000	30,000	22,000	22,000

Notes:

- 1 For comparative purposes, the proportion of fine- and coarse-grained sediment is based on locations where a core was collected.
- 2 Classification was based on a qualitative visual scheme. Classification of no-core locations may not be accurate.

TABLE 4

**ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
SEDIMENT CHARACTERIZATION AND GEOSTATISTICAL PILOT STUDY**

SUMMARY OF TOTAL PCB CONCENTRATION BY FINE AND COARSE-GRAINED SEDIMENTS

Sediment Type¹	Count (Surficial) / (All Cores)	Range (mg/kg)	Percent Detections (Surficial) / (All Cores)	Robust Log Probability Mean² (mg/kg)	Geometric Mean³ (mg/kg)	95% Confidence Interval (mg/kg)
Coarse	38 / 41	ND-3.6	68% / 63%	0.22	0.08	0.04 - 0.13
Fine	20 / 33	ND-7.8	65% / 45%	0.95	0.26	0.08 - 0.86
All	58 / 74	ND-7.8	67% / 55%	0.54	0.12	0.07 - 0.2
No Core Collected	4	—	—	—	—	—

Notes:

- 1 Classification was based on a qualitative visual scheme. Classification of no-core locations may not be accurate.
- 2 Estimates the mean of a log-normal distribution when some observations are below detection limits.
- 3 Estimates the median of a log-normal distribution.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
SEDIMENT CHARACTERIZATION AND GEOSTATISTICAL PILOT STUDY

SUMMARY OF TOTAL PCB CONCENTRATION BY RIVER CHANNEL SHAPE

River Shape	N	Min (mg/kg)	Max (mg/kg)	Geometric Mean (mg/kg)	Approximate 95 Percent Confidence Interval (mg/kg)
Inside Bend	10	ND	7.80	0.64	0.20 – 2.01
Mid-Channel	10	ND	3.60	0.09	0.03 – 0.3
Outside Bend	11	ND	6.10	0.15	0.04 – 0.59
Straight	27	ND	1.80	0.06	0.04 – 0.10

TABLE 6

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
SEDIMENT CHARACTERIZATION AND GEOSTATISTICAL PILOT STUDY

SAMPLE DELIVERY GROUP SUMMARY

40088

K22520	KPS-14	B		Yes
K22521	KPS-15	A		Yes
K22522	KPS-15	B		Yes
K22523	KPS-16	A		Yes
K22524	KPS-17	A		Yes
K22525	KPS-18	A		Yes
K22526	KPS-19	A		Yes
K22527	KPS-20	A	K22528	Yes
K22528	KPS-20	A	K22527	Yes
K22529	KPS-21	A		Yes
K22530	KPS-22	A		Yes
K22531	KPS-23	A		Yes

TABLE 6

**ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
SEDIMENT CHARACTERIZATION AND GEOSTATISTICAL PILOT STUDY**

SAMPLE DELIVERY GROUP SUMMARY

K22532	KPS-24	A		Yes
K22533			RINSE BLANK	Yes
K22534			RINSE BLANK	Yes
K22535	KPS-25	A		Yes
K22536	KPS-26	A		Yes
K22537	KPS-27	A		Yes
K22538	KPS-28	A		Yes
K22541	KPS-30	A	MS/MSD	Yes
40090				
K22500	KPS-1	A		Yes
K22501	KPS-2	A		Yes
K22502	KPS-3	A		Yes
K22503	KPS-4	A		Yes

TABLE 6

**ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
SEDIMENT CHARACTERIZATION AND GEOSTATISTICAL PILOT STUDY**

SAMPLE DELIVERY GROUP SUMMARY

K22504	KPS-4	B		Yes
K22505	KPS-5	A		Yes
K22506	KPS-6	A		Yes
K22507	KPS-7	A	K22508	Yes
K22508	KPS-7	A	K22507	Yes
K22509	KPS-7	B		Yes
K22510	KPS-8	A		Yes
K22511	KPS-9	A		Yes
K22512	KPS-9	B		Yes
K22513	KPS-10	A		Yes
K22514	KPS-11	A		Yes
K22515	KPS-12	A		Yes
K22516	KPS-13	A		Yes

TABLE 6

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
SEDIMENT CHARACTERIZATION AND GEOSTATISTICAL PILOT STUDY

SAMPLE DELIVERY GROUP SUMMARY

K22517	KPS-13	B		K22518	Yes
K22518	KPS-13	B		K22517	Yes
K22519	KPS-14	A	MS/MSD		Yes
40144					
K22539	KPS-29	A		K22540	Yes
K22540	KPS-29	A		K22539	Yes
K22542	KPS-31	A			Yes
K22543	KPS-32	A			Yes
K22544	KPS-33	A			Yes
K22545	KPS-34	A			Yes
K22546	KPS-34	B			Yes
K22547	KPS-35	A			Yes
K22548	KPS-36	A			Yes

TABLE 6

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
SEDIMENT CHARACTERIZATION AND GEOSTATISTICAL PILOT STUDY

SAMPLE DELIVERY GROUP SUMMARY

K22549	KPS-37	A	K22550	Yes	
K22550	KPS-37	A	K22549	Yes	
K22551	KPS-38	A		Yes	
K22552	KPS-39	A		Yes	
K22553	KPS-41	A		Yes	
K22554	KPS-42	A		Yes	
K22555	KPS-44	A		Yes	
K22556	KPS-45	A		Yes	
K22557	KPS-45	B		Yes	
K22558	KPS-46	A		Yes	
K22561	KPS-47	A		Yes	
40145					
K22559	KPS-46	B	K22560	Yes	

TABLE 6

**ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
SEDIMENT CHARACTERIZATION AND GEOSTATISTICAL PILOT STUDY**

SAMPLE DELIVERY GROUP SUMMARY

K22560	KPS-46	B	K22559	Yes
K22562	KPS-47	B		Yes
K22563	KPS-48	A		Yes
K22564	KPS-49	A		Yes
K22565	KPS-49	B		Yes
K22566	KPS-50	A		Yes
K22567	KPS-51	A		Yes
K22568	KPS-52	A		Yes
K22569	KPS-52	B	K22570	Yes
K22570	KPS-52	B	K22569	Yes
K22571	KPS-53	A		Yes
K22572	KPS-54	A		Yes
K22573	KPS-54	B		Yes

TABLE 6

**ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
SEDIMENT CHARACTERIZATION AND GEOSTATISTICAL PILOT STUDY**

SAMPLE DELIVERY GROUP SUMMARY

K22574	KPS-56	A			Yes
K22575	KPS-57	A			Yes
K22576	KPS-57	B			Yes
K22577	KPS-58	A			Yes
K22578	KPS-58	B			Yes
K22581	KPS-60	A	MS/MSD		Yes
40146					
K22579	KPS-59	A		K22580	Yes
K22580	KPS-59	A		K22579	Yes
K22582	KPS-62	A			Yes
K22583	KPS-62	B			Yes
K22584			RINSE BLANK		Yes
K22585			RINSE BLANK		Yes

TABLE 6

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
SEDIMENT CHARACTERIZATION AND GEOSTATISTICAL PILOT STUDY

SAMPLE DELIVERY GROUP SUMMARY



K22586	RINSE BLANK	Yes
K22587	RINSE BLANK	Yes

TABLE 7

ALLIED PAPER, INC. / PORTAGE CREEK / KALAMAZOO RIVER SUPERFUND SITE
SEDIMENT CHARACTERIZATION AND GEOSTATISTICAL PILOT STUDY

SUMMARY OF PILOT STUDY PROBING

Sample Location	Date Collected	Water Depth (ft)	Sediment Penetrated (ft)	Sediment Recovered (ft)	Depth to top of Sample (ft)	Depth to bottom of Sample (ft)	Sediment Type	Sample Description
KPS-1A	12-Oct-93	2.1	0.60	0.40	0.00	0.40	COARSE	BROWN TO BLACK TO GREY, FINE TO COARSE SAND AND GRAVEL
KPS-2A	12-Oct-93	3.9	0.80	0.70	0.00	0.70	COARSE	BROWN TO GREY FINE TO COARSE SAND & GRAVEL, SOME SHELLS & WHITE HARD MATTER
KPS-3A	12-Oct-93	1.9	1.90	1.00	0.00	1.00	COARSE	GREY-BROWN TO GREY FINE TO COARSE SAND AND GRAVEL
KPS-4A	12-Oct-93	2.5	2.30	2.20	0.00	1.00	COARSE	GREY-BROWN FINE TO COARSE SAND AND GRAVEL
KPS-4B	12-Oct-93	2.5	2.30	2.20	1.20	2.20	FINE	GREY CLAY
KPS-5A	12-Oct-93	2.5	0.50	0.50	0.00	0.50	COARSE	GREY-BROWN FINE TO COARSE SAND AND GRAVEL
KPS-6A	12-Oct-93	3.3	0.80	0.80	0.00	0.80	COARSE	BROWN TO GREY FINE TO COARSE SAND AND GRAVEL, SOME HARD WHITE CRUMBLY MATTER
KPS-7A	12-Oct-93	2.2	3.50	2.00	0.00	1.00	FINE	GREY CLAY WITH GREY-BROWN FINE TO COARSE SAND AND GRAVEL AT TOP 0.2'
DUP-1	12-Oct-93	2.2	3.50	2.00	0.00	1.00	FINE	GREY CLAY WITH GREY-BROWN FINE TO COARSE SAND AND GRAVEL AT TOP 0.2'
KPS-7B	12-Oct-93	2.2	3.50	2.00	1.00	2.00	FINE	GREY-BROWN CLAY

TABLE 7

**ALLIED PAPER, INC. / PORTAGE CREEK / KALAMAZOO RIVER SUPERFUND SITE
SEDIMENT CHARACTERIZATION AND GEOSTATISTICAL PILOT STUDY**

SUMMARY OF PILOT STUDY PROBING

Sample Location	Date Collected	Water Depth (ft)	Sediment Penetrated (ft)	Sediment Recovered (ft)	Depth to top of Sample (ft)	Depth to bottom of Sample (ft)	Sediment Type	Sample Description
KPS-8A	12-Oct-93	2.2	0.90	0.70	0.00	0.70	COARSE	BROWN TO BLACK TO GREY, FINE TO COARSE SAND AND GRAVEL
KPS-9A	12-Oct-93	3.5	3.00	1.70	0.00	1.00	FINE	GREY AND GREY-BROWN CLAY WITH BROWN FINE TO COARSE SAND & GRAVEL AT TOP 0.3'
KPS-9B	12-Oct-93	3.5	3.00	1.70	1.00	1.70	FINE	GREY AND GREY-BROWN CLAY
KPS-10A	12-Oct-93	1.0	0.80	0.60	0.00	0.60	COARSE	GREY FINE TO COARSE SAND AND GRAVEL; BROWN FINE TO MEDIUM SAND AT TOP 0.2'
KPS-11A	12-Oct-93	1.9	3.10	1.40	0.00	1.00	FINE	BROWN FINE TO COARSE SAND AND GRAVEL TO GREY AND GREY-BROWN CLAY
KPS-12A	12-Oct-93	1.9	0.90	0.70	0.00	0.70	COARSE	BROWN TO GREY, FINE TO COARSE SAND AND GRAVEL
KPS-13A	12-Oct-93	0.8	2.60	2.10	0.00	1.00	FINE	DARK GREY-BROWN FINE SAND; DARK GREY-BROWN SILT WITH TRACE FINE SAND TOP 0.3'
KPS-13B	12-Oct-93	0.8	2.60	2.10	1.00	2.00	FINE	DARK GREY-BROWN FINE SAND WITH MODERATE ORGANIC ODOR
DUP-2	12-Oct-93	0.8	2.60	2.10	1.00	2.00	FINE	DARK GREY-BROWN FINE SAND WITH MODERATE ORGANIC ODOR

TABLE 7

**ALLIED PAPER, INC. / PORTAGE CREEK / KALAMAZOO RIVER SUPERFUND SITE
SEDIMENT CHARACTERIZATION AND GEOSTATISTICAL PILOT STUDY**

SUMMARY OF PILOT STUDY PROBING

Sample Location	Date Collected	Water Depth (ft)	Sediment Penetrated (ft)	Sediment Recovered (ft)	Depth to top of Sample (ft)	Depth to bottom of Sample (ft)	Sediment Type	Sample Description
KPS-14A (MS/MSD)	12-Oct-93	3.5	3.50	2.40	0.00	1.00	FINE	GREY-BROWN SILT, SOME GREY SILTY CLAY; GREY-BROWN FINE TO MEDIUM SAND AT TOP
KPS-14B	12-Oct-93	3.5	3.50	2.40	1.40	2.40	FINE	GREY TO GREY-BROWN CLAY
KPS-15A	12-Oct-93	1.0	1.80	1.60	0.00	1.00	COARSE	BROWN FINE TO COARSE SAND AND GRAVEL
KPS-15B	12-Oct-93	1.0	1.80	1.60	1.00	1.60	FINE	GREY FINE SAND TO GREY-BROWN SILT WITH SOME FINE SAND AND GRAVEL
KPS-16A	12-Oct-93	2.2	0.60	0.50	0.00	0.70	COARSE	BROWN TO BLACK, FINE TO COARSE SAND AND GRAVEL
KPS-17A	12-Oct-93	1.3	1.20	0.80	0.00	0.80	COARSE	BROWN TO BLACK FINE TO COARSE SAND WITH DARK BROWN SILT LIKE MATERIAL AT 0.6'
KPS-18A	12-Oct-93	2.2	0.70	0.70	0.00	0.70	FINE	BROWN FINE TO COARSE SAND AND GRAVEL TO BLACK FINE SAND AND SILT LIKE MATTER
KPS-19A	12-Oct-93	2.6	1.00	0.80	0.00	0.80	COARSE	GREY-BROWN FINE TO COARSE SAND AND GRAVEL
KPS-20A	12-Oct-93	2.9	0.80	0.60	0.00	0.60	COARSE	BROWN FINE TO COARSE SAND AND GRAVEL

TABLE 7

ALLIED PAPER, INC. / PORTAGE CREEK / KALAMAZOO RIVER SUPERFUND SITE
SEDIMENT CHARACTERIZATION AND GEOSTATISTICAL PILOT STUDY

SUMMARY OF PILOT STUDY PROBING

Sample Location	Date Collected	Water Depth (ft)	Sediment Penetrated (ft)	Sediment Recovered (ft)	Depth to top of Sample (ft)	Depth to bottom of Sample (ft)	Sediment Type	Sample Description
DUP-3	12-Oct-93	2.9	0.80	0.60	0.00	0.60	COARSE	BROWN FINE TO COARSE SAND AND GRAVEL
KPS-21A	12-Oct-93	3.5	0.90	0.60	0.00	0.60	COARSE	BROWN FINE TO COARSE SAND AND GRAVEL
KPS-22A	12-Oct-93	2.9	1.00	0.60	0.00	0.60	COARSE	BROWN FINE TO COARSE SAND AND GRAVEL AND FINE WHITE HARD CRUMBLY MATERIAL
KPS-23A	12-Oct-93	2.9	0.60	0.50	0.00	0.50	COARSE	BROWN FINE TO COARSE SAND AND GRAVEL
KPS-24A	12-Oct-93	2.1	0.60	0.40	0.00	0.40	COARSE	BROWN TO BLACK, FINE TO COARSE SAND AND GRAVEL
RB-1 (RINSE BLANK)	13-Oct-93	0.0	0.00	0.00	0.00	0.00		
RB-2 (RINSE BLANK)	13-Oct-93	0.0	0.00	0.00	0.00	0.00		
KPS-25A	13-Oct-93	3.4	2.30	1.30	0.00	1.00	COARSE	BROWN TO GREY, FINE TO COARSE SAND AND GRAVEL
KPS-26A	13-Oct-93	3.9	1.50	1.40	0.00	1.00	FINE	BROWN TO BLACK PEAT, SOME SAND AND GRAVEL; BROWN FINE SAND AT TOP

TABLE 7

ALLIED PAPER, INC. / PORTAGE CREEK / KALAMAZOO RIVER SUPERFUND SITE
SEDIMENT CHARACTERIZATION AND GEOSTATISTICAL PILOT STUDY

SUMMARY OF PILOT STUDY PROBING

Sample Location	Date Collected	Water Depth (ft)	Sediment Penetrated (ft)	Sediment Recovered (ft)	Depth to top of Sample (ft)	Depth to bottom of Sample (ft)	Sediment Type	Sample Description
KPS-27A	13-Oct-93	2.4	0.90	0.80	0.00	0.80	COARSE	GREY-BROWN TO BROWN, FINE TO COARSE SAND AND GRAVEL
KPS-28A	13-Oct-93	1.8	1.80	1.30	0.00	1.00	COARSE	LIGHT BROWN VERY FINE TO COARSE SAND WITH SOME GRAVEL
KPS-29A	13-Oct-93	4.0	1.10	1.00	0.00	1.00	COARSE	GREY-BROWN FINE TO COARSE SAND AND GRAVEL WITH SOME BROWN SILT
DUP-4	13-Oct-93	4.0	1.10	1.00	0.00	1.00	COARSE	GREY-BROWN FINE TO COARSE SAND AND GRAVEL WITH SOME BROWN SILT
KPS-30A (MS/MSD)	13-Oct-93	3.7	1.40	0.90	0.00	0.90	COARSE	GREY-BROWN FINE TO COARSE SAND AND GRAVEL; BLACK SILT-LIKE MATERIAL AT 0.6'
KPS-31A	13-Oct-93	3.9	1.20	1.00	0.00	1.00	COARSE	BROWN TO BLACK TO GREY, FINE TO COARSE SAND AND GRAVEL
KPS-32A	13-Oct-93	3.9	1.20	1.00	0.00	1.00	COARSE	BROWN FINE TO COARSE SAND AND GRAVEL WITH WHITE HARD CRUMBLY MATERIAL
KPS-33A	13-Oct-93	3.1	1.30	1.00	0.00	1.00	COARSE	GREY-BROWN FINE TO COARSE SAND AND GRAVEL
KPS-34A	13-Oct-93	2.7	2.00	1.80	0.00	1.00	COARSE	LIGHT BROWN TO BROWN, VERY FINE TO COARSE SAND AND GRAVEL

TABLE 7

ALLIED PAPER, INC. / PORTAGE CREEK / KALAMAZOO RIVER SUPERFUND SITE
SEDIMENT CHARACTERIZATION AND GEOSTATISTICAL PILOT STUDY

SUMMARY OF PILOT STUDY PROBING

Sample Location	Date Collected	Water Depth (ft)	Sediment Penetrated (ft)	Sediment Recovered (ft)	Depth to top of Sample (ft)	Depth to bottom of Sample (ft)	Sediment Type	Sample Description
KPS-34B	13-Oct-93	2.7	2.00	1.80	1.00	1.80	COARSE	LIGHT GREY FINE TO MEDIUM SAND WITH SOME GRAVEL
KPS-35A	13-Oct-93	1.5	1.20	1.00	0.00	1.00	COARSE	BROWN TO GREY, FINE TO COARSE SAND AND GRAVEL
KPS-36A	13-Oct-93	2.2	1.80	1.20	0.00	1.00	COARSE	GREY-BROWN SILT AND SOME FINE SAND TO GREY-BROWN FINE TO COARSE SAND, GRAVEL
KPS-37A	13-Oct-93	3.6	2.00	1.10	0.00	1.00	COARSE	GREY-BROWN FINE TO COARSE SAND AND GRAVEL
DUP-5	13-Oct-93	3.6	2.00	1.10	0.00	1.00	COARSE	GREY-BROWN FINE TO COARSE SAND AND GRAVEL
KPS-38A	13-Oct-93	3.8	2.10	1.30	0.00	1.00	COARSE	BROWN FINE TO COARSE SAND AND GRAVEL; GREY FINE TO COARSE SAND FROM 0.7'-1.0'
KPS-39A	13-Oct-93	1.6	1.80	1.30	0.00	1.00	COARSE	DARK GREY-BROWN FINE SAND WITH SOME GRAVEL, SLIGHT ORGANIC ODOR
KPS-41A	13-Oct-93	6.0	0.70	0.60	0.00	0.60	COARSE	GREY-BROWN FINE TO COARSE SAND, GRAVEL, SOME FINE WHITE HARD CRUMBLY MATTER

TABLE 7

ALLIED PAPER, INC. / PORTAGE CREEK / KALAMAZOO RIVER SUPERFUND SITE
SEDIMENT CHARACTERIZATION AND GEOSTATISTICAL PILOT STUDY

SUMMARY OF PILOT STUDY PROBING

Sample Location	Date Collected	Water Depth (ft)	Sediment Penetrated (ft)	Sediment Recovered (ft)	Depth to top of Sample (ft)	Depth to bottom of Sample (ft)	Sediment Type	Sample Description
KPS-42A	13-Oct-93	2.8	1.90	1.40	0.00	1.00	FINE	GREY FINE TO COARSE SAND AND GRAVEL; GREY CLAY-LIKE MATERIAL AT TOP 0.3'
KPS-44A	13-Oct-93	3.0	1.60	1.00	0.00	1.00	FINE	GREY-BROWN FINE TO COARSE SAND WITH GREY CLAY AT 0.6'
KPS-45A	13-Oct-93	2.3	3.40	2.20	0.00	1.00	FINE	BROWN FINE SAND TO DARK GREY TO BLACK FINE SAND, SOME SILT & ORGANIC MATTER
KPS-45B	13-Oct-93	2.3	3.40	2.20	1.20	2.20	FINE	DARK BROWN TO BLACK SILT AND FINE SAND WITH A LOT OF ORGANIC MATTER
KPS-46A	13-Oct-93	1.8	7.20	5.30	0.00	1.00	FINE	GREY-BROWN FINE SAND AT TOP & BOTTOM WITH GREY CLAY-LIKE MATERIAL IN MIDDLE
KPS-46B	13-Oct-93	1.8	7.20	5.30	4.30	5.30	FINE	LIGHT GREY VERY FINE TO FINE SAND, TO GREY FINE TO COARSE SAND
DUP-6	13-Oct-93	1.8	7.20	5.30	4.30	5.30	FINE	LIGHT GREY VERY FINE TO FINE SAND, TO GREY FINE TO COARSE SAND
KPS-47A	13-Oct-93	1.6	2.50	2.00	0.00	1.00	FINE	GREY-BROWN FINE SAND, TO BLACK SILT-LIKE MATERIAL WITH STRONG ORGANIC ODOR

TABLE 7

**ALLIED PAPER, INC. / PORTAGE CREEK / KALAMAZOO RIVER SUPERFUND SITE
SEDIMENT CHARACTERIZATION AND GEOSTATISTICAL PILOT STUDY**

SUMMARY OF PILOT STUDY PROBING

Sample Location	Date Collected	Water Depth (ft)	Sediment Penetrated (ft)	Sediment Recovered (ft)	Depth to top of Sample (ft)	Depth to bottom of Sample (ft)	Sediment Type	Sample Description
KPS-47B	13-Oct-93	1.6	2.50	2.00	1.00	2.00	FINE	BLACK SILT MATERIAL, STRONG ORGANIC ODOR; GREY FINE SAND; BLACK SILT & PEAT
KPS-48A	13-Oct-93	5.5	1.00	1.00	0.00	1.00	COARSE	BROWN VERY FINE TO COARSE SAND, SOME GRAVEL
KPS-49A	13-Oct-93	1.2	4.30	3.20	0.00	1.00	FINE	GREY-BROWN FINE SAND, TO DARK GREY-BROWN FINE SAND WITH SOME ORGANIC MATTER
KPS-49B	13-Oct-93	1.2	4.30	3.20	2.20	3.20	FINE	DARK GREY-BROWN SOFT SILTY CLAY-LIKE MATERIAL WITH A STRONG ORGANIC ODOR
KPS-50A	13-Oct-93	4.8	1.80	1.40	0.00	1.00	COARSE	BROWN FINE TO COARSE SAND AND GRAVEL WITH A TRACE OF GREY CLAY-LIKE MATERIAL
KPS-51A	13-Oct-93	5.7	1.10	0.80	0.00	0.80	COARSE	BROWN TO GREY, FINE TO COARSE SAND AND GRAVEL
KPS-52A	13-Oct-93	4.5	2.00	1.60	0.00	1.00	COARSE	GREY-BROWN FINE TO COARSE SAND AND GRAVEL WITH ORANGE-BROWN SAND FROM 0.2'-0.4'

TABLE 7

**ALLIED PAPER, INC. / PORTAGE CREEK / KALAMAZOO RIVER SUPERFUND SITE
SEDIMENT CHARACTERIZATION AND GEOSTATISTICAL PILOT STUDY**

SUMMARY OF PILOT STUDY PROBING

Sample Location	Date Collected	Water Depth (ft)	Sediment Penetrated (ft)	Sediment Recovered (ft)	Depth to top of Sample (ft)	Depth to bottom of Sample (ft)	Sediment Type	Sample Description
KPS-52B	13-Oct-93	4.5	2.00	1.60	1.00	1.60	COARSE	GREY FINE TO COARSE SAND, SOME GRAVEL; LIGHT GREY FINE SAND FROM 1.2'-1.6'
DUP-7	13-Oct-93	4.5	2.00	1.60	1.00	1.60	COARSE	GREY FINE TO COARSE SAND, SOME GRAVEL; LIGHT GREY FINE SAND FROM 1.2'-1.6'
KPS-53A	13-Oct-93	3.7	1.30	1.00	0.00	1.00	FINE	GREY CLAY TO BROWN FINE TO COARSE SAND, SOME GRAVEL
KPS-54A	13-Oct-93	2.7	2.00	1.60	0.00	1.00	FINE	LIGHT BROWN TO DARK BROWN TO BLACK FINE SAND WITH BLACK SILT AT BOTTOM
KPS-54B	13-Oct-93	2.7	2.00	1.60	1.00	1.60	FINE	DARK GREY TO BLACK SILT-LIKE MATERIAL WITH A MODERATE ORGANIC ODOR
KPS-56A	13-Oct-93	3.9	1.20	1.00	0.00	1.00	FINE	GREY-BROWN FINE SAND, GRAVEL; TO GREY CLAY-LIKE MATTER; TO GREY PACKED SAND
KPS-57A	14-Oct-93	0.8	5.60	3.20	0.00	1.00	FINE	GREY-BROWN FINE SAND WITH DARK BROWN TO BLACK ORGANIC MATTER IN MIDDLE

TABLE 7

**ALLIED PAPER, INC. / PORTAGE CREEK / KALAMAZOO RIVER SUPERFUND SITE
SEDIMENT CHARACTERIZATION AND GEOSTATISTICAL PILOT STUDY**

SUMMARY OF PILOT STUDY PROBING

Sample Location	Date Collected	Water Depth (ft)	Sediment Penetrated (ft)	Sediment Recovered (ft)	Depth to top of Sample (ft)	Depth to bottom of Sample (ft)	Sediment Type	Sample Description
KPS-57B	14-Oct-93	0.8	5.60	3.20	2.20	3.20	COARSE	DARK BROWN TO BLACK TO GREY-BROWN FINE TO COARSE SAND, SOME GRAVEL AT BOTTOM
KPS-58A	14-Oct-93	2.9	3.40	2.00	0.00	1.00	COARSE	GREY-BROWN FINE TO MEDIUM SAND, SOME GRAVEL, DARK BROWN ORGANIC MATTER
KPS-58B	14-Oct-93	2.9	3.40	2.00	1.00	2.00	FINE	DARK BROWN TO BLACK COARSE SAND AND GRAVEL; GREY CLAY FROM 1.5'-2.0'
KPS-59A	14-Oct-93	7.5	2.50	1.40	0.00	1.00	FINE	GREY-BROWN FINE TO COARSE SAND TO GREY-BROWN TO BLACK SILT WITH ORGANIC ODOR
DUP-8	14-Oct-93	7.5	2.50	1.40	0.00	1.00	FINE	GREY-BROWN FINE TO COARSE SAND TO GREY-BROWN TO BLACK SILT WITH ORGANIC ODOR
KPS-60A (MS/MSD)	14-Oct-93	3.3	1.70	1.10	0.00	1.00	FINE	GREY CLAY
KPS-62A	14-Oct-93	2.7	4.60	3.10	0.00	1.00	FINE	DARK GREY SILT AND GREY CLAY-LIKE MATERIAL TO LIGHT GREY FINE SAND
KPS-62B	14-Oct-93	2.7	4.60	3.10	2.10	3.10	FINE	GREY-BROWN PEAT, SILT, SAND; GREY-BROWN SILTY CLAY-LIKE MATTER IN MIDDLE

TABLE 7

**ALLIED PAPER, INC. / PORTAGE CREEK / KALAMAZOO RIVER SUPERFUND SITE
SEDIMENT CHARACTERIZATION AND GEOSTATISTICAL PILOT STUDY**

SUMMARY OF PILOT STUDY PROBING

Sample Location	Date Collected	Water Depth (ft)	Sediment Penetrated (ft)	Sediment Recovered (ft)	Depth to top of Sample (ft)	Depth to bottom of Sample (ft)	Sediment Type	Sample Description
RB-3 (RINSE BLANK)	14-Oct-93	0.0	0.00	0.00	0.00	0.00		
RB-4 (RINSE BLANK)	14-Oct-93	0.0	0.00	0.00	0.00	0.00		
RB-5 (RINSE BLANK)	15-Oct-93	0.0	0.00	0.00	0.00	0.00		
RB-6 (RINSE BLANK)	15-Oct-93	0.0	0.00	0.00	0.00	0.00		

TABLE 8

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
SEDIMENT CHARACTERIZATION AND GEOSTATISTICAL PILOT STUDY

SUMMARY OF PCB RESULTS FOR GEOSTATISTICAL PILOT STUDY (mg/kg)

Location Depth (ft) Sample ID	KPS-1A 0.00-0.40 K22500	KPS-2A 0.00-0.70 K22501	KPS-3A 0.00-1.00 K22502	KPS-4A 0.00-1.00 K22503	KPS-4B 1.20-2.20 K22504	KPS-5A 0.00-0.50 K22505
Aroclor-1016	ND (0.057 U)	ND (0.056 U)	ND (0.063 U)	ND (0.058 U)	ND (0.070 UJ)	ND (0.060 UJ)
Aroclor-1242	ND (0.057 U)	ND (0.056 U)	ND (0.063 U)	0.16	ND (0.070 UJ)	ND (0.060 UJ)
Aroclor-1248	0.067	ND (0.056 U)	0.049 J	0.25	ND (0.070 UJ)	0.14 J
Aroclor-1254	ND (0.057 U)	ND (0.056 U)	ND (0.063 U)	0.029 J	ND (0.070 UJ)	0.12 J
Aroclor-1260	ND (0.057 U)	ND (0.056 U)	ND (0.063 U)	ND (0.058 U)	ND (0.070 UJ)	ND (0.060 UJ)
Total	0.067	0.056 U	0.049 J	0.439	0.07 UJ	0.26 J

Location Depth (ft) Sample ID	KPS-6A 0.00-0.80 K22506	KPS-7A 0.00-1.00 K22507	KPS-7A (Dup) 0.00-1.00 K22508	KPS-7B 1.00-2.00 K22509	KPS-8A 0.00-0.70 K22510	KPS-9A 0.00-1.00 K22511
Aroclor-1016	ND (0.055 U)	ND (0.087 U)	ND (0.069 U)	ND (0.068 U)	ND (0.062 U)	ND (0.060 U)
Aroclor-1242	ND (0.055 U)	ND (0.087 U)	ND (0.069 U)	ND (0.068 U)	ND (0.062 U)	ND (0.060 U)
Aroclor-1248	ND (0.055 U)	ND (0.087 U)	ND (0.069 U)	ND (0.068 U)	0.098	ND (0.060 U)
Aroclor-1254	ND (0.055 U)	ND (0.087 U)	ND (0.069 U)	ND (0.068 U)	ND (0.062 U)	ND (0.060 U)
Aroclor-1260	ND (0.055 U)	ND (0.087 U)	ND (0.069 U)	ND (0.068 U)	ND (0.062 U)	ND (0.060 U)
Total	0.055 U	0.087 U	0.069 U	0.068 U	0.098	0.060 U

TABLE 8

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
SEDIMENT CHARACTERIZATION AND GEOSTATISTICAL PILOT STUDY

SUMMARY OF PCB RESULTS FOR GEOSTATISTICAL PILOT STUDY (mg/kg)

Location Depth (ft) Sample ID	KPS-9B 1.00-1.70 K22512	KPS-10A 0.00-0.60 K22513	KPS-11A 0.00-1.00 K22514	KPS-12A 0.00-0.70 K22515	KPS-13A 0.00-1.00 K22516	KPS-13B 1.00-2.00 K22517
Aroclor-1016	ND (0.068 UJ)	ND (0.061 U)	ND (0.063 UJ)	ND (0.056 U)	ND (0.086 U)	ND (0.067 U)
Aroclor-1242	ND (0.068 UJ)	ND (0.061 U)	ND (0.063 UJ)	ND (0.056 U)	0.93	0.27
Aroclor-1248	ND (0.068 UJ)	0.24	0.053 J	0.084	ND (0.086 U)	0.058 J
Aroclor-1254	ND (0.068 UJ)	0.14	ND (0.063 UJ)	0.072	0.15	0.058 J
Aroclor-1260	ND (0.068 UJ)	0.039 J	ND (0.063 UJ)	ND (0.056 U)	ND (0.086 U)	ND (0.067 U)
Total	0.068 UJ	0.419	0.053 J	0.156	.1080	0.386

Location Depth (ft) Sample ID	KPS-13B (Dup) 1.00-2.00 K22518	KPS-14A 0.00-1.00 K22519	KPS-14B 1.40-2.40 K22520	KPS-15A 0.00-1.00 K22521	KPS-15B 1.00-1.60 K22522	KPS-16A 0.00-0.70 K22523
Aroclor-1016	ND (0.069 U)	ND (0.081 U)	ND (0.069 U)	ND (0.054 U)	ND (0.067 U)	ND (0.057 U)
Aroclor-1242	ND (0.069 U)	0.080 J	ND (0.069 U)	ND (0.054 U)	ND (0.067 U)	0.027 J
Aroclor-1248	0.037 J	ND (0.081 U)	ND (0.069 U)	0.030 J	ND (0.067 U)	ND (0.057 U)
Aroclor-1254	0.027 J	ND (0.081 U)	ND (0.069 U)	ND (0.054 U)	ND (0.067 U)	ND (0.057 U)
Aroclor-1260	ND (0.069 U)	ND (0.081 U)	ND (0.069 U)	ND (0.054 U)	ND (0.067 U)	ND (0.057 U)
Total	0.064 J	0.08 J	0.069 U	0.03 J	0.067 U	0.027 J

TABLE 8

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
SEDIMENT CHARACTERIZATION AND GEOSTATISTICAL PILOT STUDY

SUMMARY OF PCB RESULTS FOR GEOSTATISTICAL PILOT STUDY (mg/kg)

Location Depth (ft) Sample ID	KPS-17A 0.00-0.80 K22524	KPS-18A 0.00-0.70 K22525	KPS-19A 0.00-0.80 K22526	KPS-20A 0.00-0.60 K22527	KPS-20A (Dup) 0.00-0.60 K22528	KPS-21A 0.00-0.60 K22529
Aroclor-1016	ND (0.069 U)	ND (0.064 U)	ND (0.059 U)	ND (0.056 U)	ND (0.056 U)	ND (0.059 U)
Aroclor-1242	ND (0.069 U)	ND (0.064 U)	ND (0.059 U)	0.029 J	ND (0.056 U)	ND (0.059 U)
Aroclor-1248	ND (0.069 U)	ND (0.064 U)	0.027 J	ND (0.056 U)	0.025 J	ND (0.059 U)
Aroclor-1254	ND (0.069 U)	ND (0.064 U)	ND (0.059 U)	ND (0.056 U)	ND (0.056 U)	ND (0.059 U)
Aroclor-1260	ND (0.069 U)	ND (0.064 U)	ND (0.059 U)	ND (0.056 U)	ND (0.056 U)	ND (0.059 U)
Total	0.069 U	0.064 U	0.027 J	0.029 J	0.025 J	0.059 U

Location Depth (ft) Sample ID	KPS-22A 0.00-0.60 K22530	KPS-23A 0.00-0.50 K22531	KPS-24A 0.00-0.40 K22532	KPS-25A 0.00-1.00 K22535	KPS-26A 0.00-1.00 K22536	KPS-27A 0.00-0.80 K22537
Aroclor-1016	ND (0.058 U)	ND (0.066 U)	ND (0.056 U)	ND (0.055 U)	ND (0.17 U)	ND (0.055 U)
Aroclor-1242	ND (0.058 U)	ND (0.066 U)	0.024 J	ND (0.055 U)	ND (0.17 U)	ND (0.055 U)
Aroclor-1248	0.041 J	0.35	ND (0.056 U)	ND (0.055 U)	ND (0.17 U)	ND (0.055 U)
Aroclor-1254	ND (0.058 U)	0.10	ND (0.056 U)	ND (0.055 U)	ND (0.17 U)	ND (0.055 U)
Aroclor-1260	ND (0.058 U)	0.026 J	ND (0.056 U)	ND (0.055 U)	ND (0.17 U)	ND (0.055 U)
Total	0.041 J	0.476	0.024 J	0.055 U	0.17 U	0.055 U

TABLE 8

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
SEDIMENT CHARACTERIZATION AND GEOSTATISTICAL PILOT STUDY

SUMMARY OF PCB RESULTS FOR GEOSTATISTICAL PILOT STUDY (mg/kg)

Location Depth (ft) Sample ID	KPS-28A 0.00-1.00 K22538	KPS-29A 0.00-1.00 K22539	KPS-29A (Dup) 0.00-1.00 K22540	KPS-30A 0.00-0.90 K22541	KPS-31A 0.00-1.00 K22542	KPS-32A 0.00-1.00 K22543
Aroclor-1016	ND (0.055 U)	ND (0.056 U)	ND (0.056 U)	ND (0.071 U)	ND (0.061 U)	ND (0.58 U)
Aroclor-1242	ND (0.055 U)	0.045 J	ND (0.056 U)	ND (0.071 U)	ND (0.061 U)	ND (0.58 U)
Aroclor-1248	ND (0.055 U)	ND (0.056 U)	ND (0.056 U)	ND (0.071 U)	ND (0.061 U)	ND (0.58 U)
Aroclor-1254	ND (0.055 U)	0.055 J	ND (0.056 U)	ND (0.071 U)	ND (0.061 U)	3.6
Aroclor-1260	ND (0.055 U)	ND (0.056 U)	ND (0.056 U)	ND (0.071 U)	ND (0.061 U)	ND (0.58 U)
Total	0.055 U	0.100 J	0.056 U	0.071 U	0.061 U	3.6

Location Depth (ft) Sample ID	KPS-33A 0.00-1.00 K22544	KPS-34A 0.00-1.00 K22545	KPS-34B 1.00-1.80 K22546	KPS-35A 0.00-1.00 K22547	KPS-36A 0.00-1.00 K22548	KPS-37A 0.00-1.00 K22549
Aroclor-1016	ND (0.057 U)	ND (0.062 U)	ND (0.061 U)	ND (0.056 U)	0.029 J	ND (0.060 U)
Aroclor-1242	ND (0.057 U)	ND (0.062 U)	ND (0.061 U)	ND (0.056 U)	ND (0.059 U)	ND (0.060 U)
Aroclor-1248	0.11	0.58	ND (0.061 U)	ND (0.056 U)	ND (0.059 U)	0.14
Aroclor-1254	0.18	ND (0.062 U)	ND (0.061 U)	0.044 J	0.041 J	0.051 J
Aroclor-1260	ND (0.057 U)	0.062	ND (0.061 UJ)	ND (0.056 U)	ND (0.059 U)	ND (0.060 U)
Total	0.29	0.642	0.061 U	0.044 J	0.070 J	0.191

TABLE 8

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
SEDIMENT CHARACTERIZATION AND GEOSTATISTICAL PILOT STUDY

SUMMARY OF PCB RESULTS FOR GEOSTATISTICAL PILOT STUDY (mg/kg)

Location Depth (ft) Sample ID	KPS-37A (Dup) 0.00-1.00 K22550	KPS-38A 0.00-1.00 K22551	KPS-39A 0.00-1.00 K22552	KPS-41A 0.00-0.60 K22553	KPS-42A 0.00-1.00 K22554	KPS-44A 0.00-1.00 K22555
Aroclor-1016	ND (0.057 U)	ND (0.057 U)	ND (0.064 U)	ND (0.059 U)	ND (0.68 U)	ND (0.063 U)
Aroclor-1242	ND (0.057 U)	ND (0.057 U)	0.27	ND (0.059 U)	5.7	0.079
Aroclor-1248	0.055 J	ND (0.057 U)	0.080	ND (0.059 U)	2.1	ND (0.063 U)
Aroclor-1254	0.028 J	ND (0.057 U)	0.14	0.024 J	ND (0.68 U)	ND (0.063 U)
Aroclor-1260	ND (0.057 U)	ND (0.057 U)	0.033 J	ND (0.059 U)	ND (0.68 U)	ND (0.063 U)
Total	0.083 J	0.057 U	0.523	0.024 J	7.80	0.079

Location Depth (ft) Sample ID	KPS-45A 0.00-1.00 K22556	KPS-45B 1.20-2.20 K22557	KPS-46A 0.00-1.00 K22558	KPS-46B 4.30-5.30 K22559	KPS-46B (Dup) 4.30-5.30 K22560	KPS-47A 0.00-1.00 K22561
Aroclor-1016	ND (0.41 U)	ND (0.87 U)	ND (0.34 U)	ND (0.065 U)	ND (0.060 U)	ND (0.072 U)
Aroclor-1242	ND (0.41 U)	ND (0.87 U)	ND (0.34 U)	ND (0.065 U)	ND (0.060 U)	ND (0.072 U)
Aroclor-1248	3.6	5.0	1.4	ND (0.065 U)	ND (0.060 U)	1.0
Aroclor-1254	ND (0.41 U)	ND (0.87 U)	0.65	ND (0.065 U)	ND (0.060 U)	ND (0.072 U)
Aroclor-1260	0.36 J	0.43 J	0.17 J	ND (0.065 U)	ND (0.060 U)	0.11
Total	3.96	5.43	2.22	0.065 U	0.06 U	1.11

TABLE 8

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
SEDIMENT CHARACTERIZATION AND GEOSTATISTICAL PILOT STUDY

SUMMARY OF PCB RESULTS FOR GEOSTATISTICAL PILOT STUDY (mg/kg)

Location Depth (ft) Sample ID	KPS-47B 1.00-2.00 K22562	KPS-48A 0.00-1.00 K22563	KPS-49A 0.00-1.00 K22564	KPS-49B 2.20-3.20 K22565	KPS-50A 0.00-1.00 K22566	KPS-51A 0.00-0.80 K22567
Aroclor-1016	ND (0.094 U)	ND (0.060 U)	ND (0.069 U)	ND (0.12 U)	ND (0.057 U)	ND (0.060 U)
Aroclor-1242	ND (0.094 U)	0.027 J	0.23	ND (0.12 U)	0.078	ND (0.060 U)
Aroclor-1248	ND (0.094 U)	ND (0.060 U)	ND (0.069 U)	ND (0.12 U)	ND (0.057 U)	ND (0.060 U)
Aroclor-1254	ND (0.094 U)	ND (0.060 U)	0.047 J	ND (0.12 U)	0.37	ND (0.060 U)
Aroclor-1260	ND (0.094 U)	ND (0.060 U)	ND (0.069 U)	ND (0.12 U)	ND (0.057 U)	ND (0.060 U)
Total	0.094 U	0.027 J	0.277	0.12 U	0.448	0.06 U

Location Depth (ft) Sample ID	KPS-52A 0.00-1.00 K22568	KPS-52B 1.00-1.60 K22569	KPS-52B (Dup) 1.00-1.60 K22570	KPS-53A 0.00-1.00 K22571	KPS-54A 0.00-1.00 K22572	KPS-54B 1.00-1.60 K22573
Aroclor-1016	ND (0.056 U)	ND (0.060 U)	ND (0.059 U)	ND (0.70 U)	0.074 J	ND (0.12 U)
Aroclor-1242	ND (0.056 U)	ND (0.060 U)	ND (0.059 U)	ND (0.70 U)	ND (0.074 U)	ND (0.12 U)
Aroclor-1248	ND (0.056 U)	ND (0.060 U)	ND (0.059 U)	5.5	0.16	ND (0.12 U)
Aroclor-1254	ND (0.056 U)	ND (0.060 U)	ND (0.059 U)	ND (0.70 U)	0.081	ND (0.12 U)
Aroclor-1260	ND (0.056 U)	ND (0.060 U)	ND (0.059 U)	0.57 J	ND (0.074 U)	ND (0.12 U)
Total	0.056 U	0.06 U	0.059 U	6.07	0.315	0.12 U

TABLE 8

**ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
SEDIMENT CHARACTERIZATION AND GEOSTATISTICAL PILOT STUDY**

SUMMARY OF PCB RESULTS FOR GEOSTATISTICAL PILOT STUDY (mg/kg)

Location Depth (ft) Sample ID	KPS-56A 0.00-1.00 K22574	KPS-57A 0.00-1.00 K22575	KPS-57B 2.20-3.20 K22576	KPS-58A 0.00-1.00 K22577	KPS-58B 1.00-2.00 K22578	KPS-59A 0.00-1.00 K22579
Aroclor-1016	ND (0.062 U)	ND (0.15 U)	ND (0.061 U)	ND (0.17 U)	ND (0.064 U)	ND (0.11 U)
Aroclor-1242	ND (0.062 U)	0.72	ND (0.061 U)	ND (0.17 U)	ND (0.064 U)	ND (0.11 U)
Aroclor-1248	ND (0.062 U)	ND (0.15 U)	ND (0.061 U)	0.26	ND (0.064 U)	ND (0.11 U)
Aroclor-1254	ND (0.062 U)	0.73	ND (0.061 U)	0.37	ND (0.064 U)	ND (0.11 U)
Aroclor-1260	ND (0.062 U)	ND (0.15 U)	ND (0.061 U)	0.098	ND (0.064 U)	ND (0.11 U)
Total	0.062 U	1.45	0.061 U	0.728	0.064 U	0.11 U

Location Depth (ft) Sample ID	KPS-59A (Dup) 0.00-1.00 K22580	KPS-60A 0.00-1.00 K22581	KPS-62A 0.00-1.00 K22582	KPS-62B 2.10-3.10 K22583
Aroclor-1016	ND (0.097 UJ)	ND (0.065 U)	ND (0.082 U)	ND (0.11 U)
Aroclor-1242	ND (0.097 UJ)	ND (0.065 U)	ND (0.082 U)	ND (0.11 U)
Aroclor-1248	ND (0.097 UJ)	ND (0.065 U)	0.83	ND (0.11 U)
Aroclor-1254	ND (0.097 UJ)	ND (0.065 U)	ND (0.082 U)	ND (0.11 U)
Aroclor-1260	ND (0.097 UJ)	ND (0.065 U)	0.085	ND (0.11 U)
Total	0.097 UJ	0.065 U	0.915	0.11 U

Notes:

ND - Not detected.

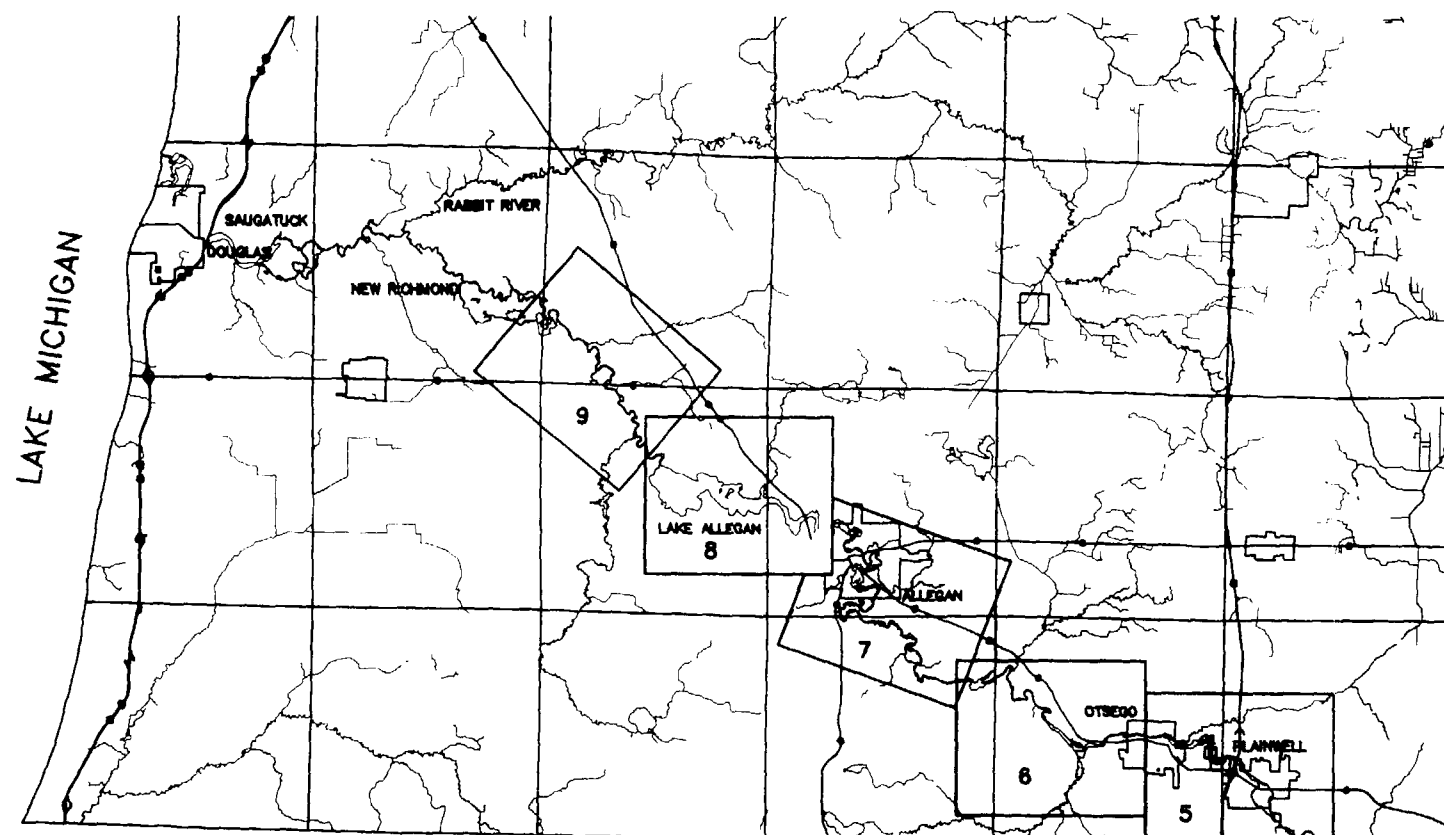
Dup - Duplicate sample.

Notes Explaining Data Qualifiers:

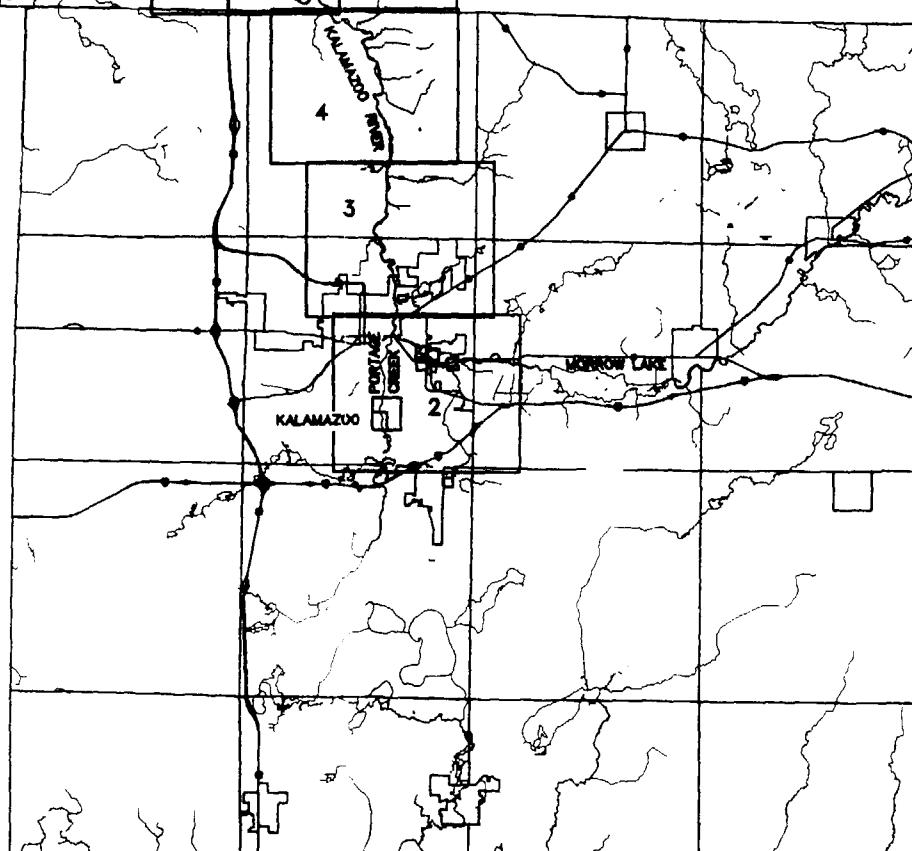
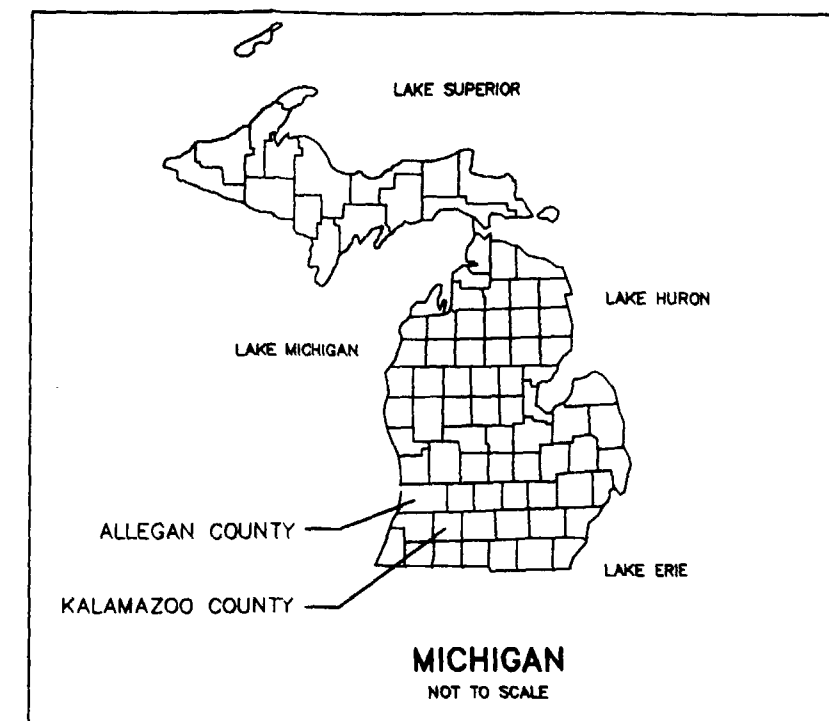
J - The compound was positively identified. However, the associated numerical value is an estimated concentration only.

U - The compound was analyzed for but not detected. The associated value is the compound quantitation limit.

UJ - The compound was not detected above the reported sample quantitation limit. However, the reported limit is approximate and may or may not represent the actual limit of quantitation.



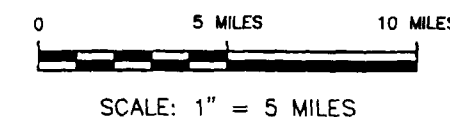
ALLEGAN COUNTY



KALAMAZOO COUNTY

LEGEND

2 SHEET NO. AND AREA DESCRIBED

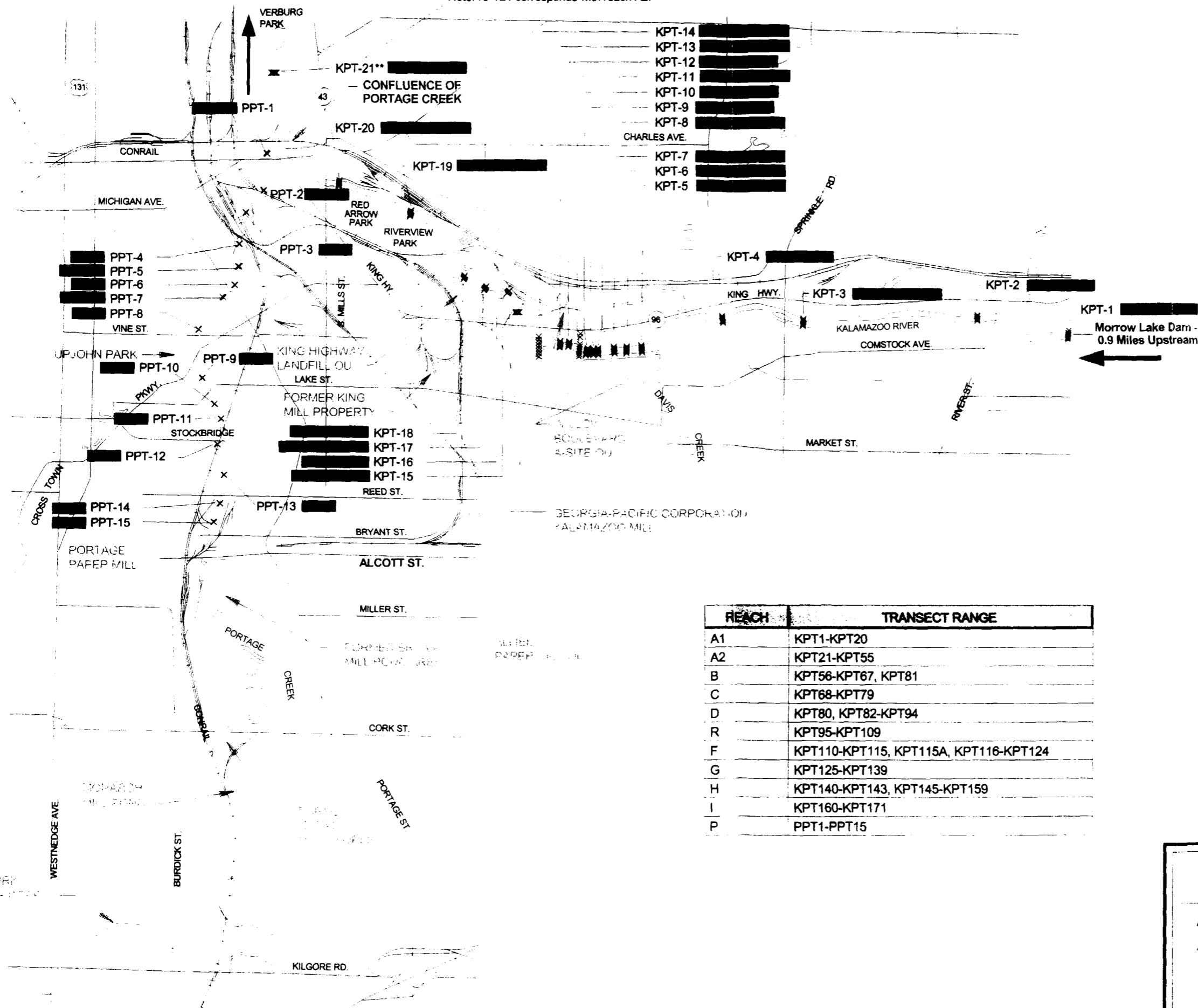


ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
TECHNICAL MEMORANDUM 10 SEDIMENT
CHARACTERIZATION/GEOSTATISTICAL PILOT STUDY

INDEX TO DRAWINGS

FIGURE
1

**Note: KPT21 corresponds with reach A2.



REACH	TRANSECT RANGE
A1	KPT1-KPT20
A2	KPT21-KPT55
B	KPT56-KPT67, KPT81
C	KPT68-KPT79
D	KPT80, KPT82-KPT94
R	KPT95-KPT109
F	KPT110-KPT115, KPT115A, KPT116-KPT124
G	KPT125-KPT139
H	KPT140-KPT143, KPT145-KPT159
I	KPT160-KPT171
P	PPT1-PPT15

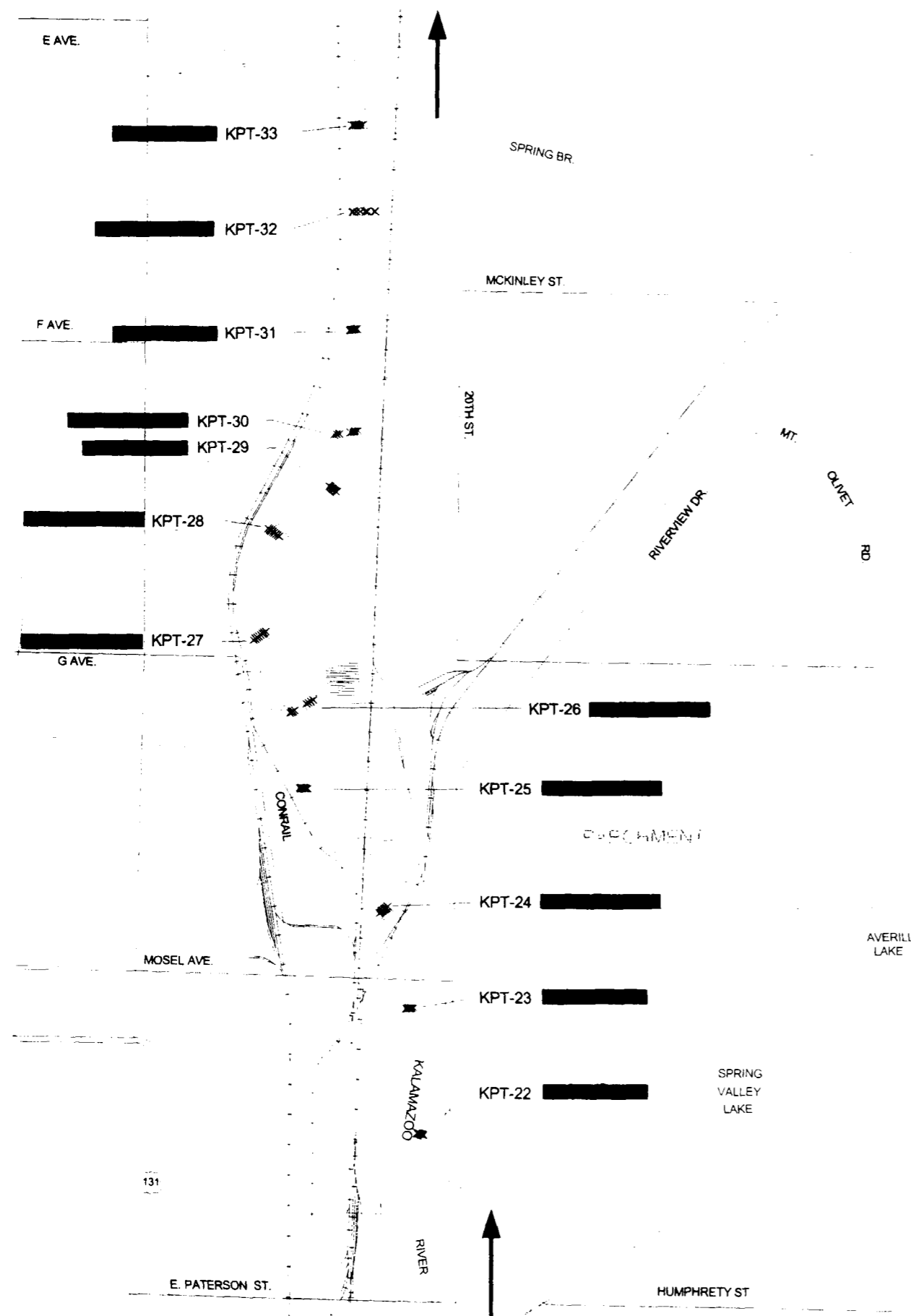
Each interval of a bar represents one sampling location along a transect. The left side of the bar corresponds with the left bank of the river looking downstream.

Note: Base map data derived from MIRIS. All transect locations surveyed. Discrepancies attributable to base map inaccuracy.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
TECHNICAL MEMORANDUM ON SEDIMENT
CHARACTERIZATION & GEOSTATISTICAL ANALYSIS

PORTAGE CREEK/
KALAMAZOO RIVER
CONFLUENCE

FIGURE
2



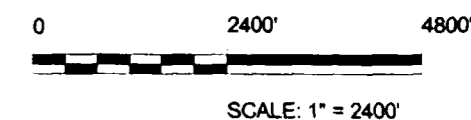
REACH	TRANSECT RANGE
A1	KPT1-KPT20
A2	KPT21-KPT55
B	KPT56-KPT67, KPT81
C	KPT68-KPT79
D	KPT80, KPT82-KPT94
R	KPT95-KPT109
F	KPT110-KPT115, KPT115A, KPT116-KPT124
G	KPT125-KPT139
H	KPT140-KPT143, KPT145-KPT159
I	KPT160-KPT171
P	PPT1-PPT15

LEGEND

- RAILROAD RIGHT-OF-WAY
- APPROXIMATE DELINEATION OF PRESENT CREEK CHANNEL
- SAMPLING LOCATION
- FINE SEDIMENT
- COARSE SEDIMENT
- DIRECTION OF FLOW

Each interval of a bar represents one sampling location along a transect. The left side of the bar corresponds with the left bank of the river looking downstream.

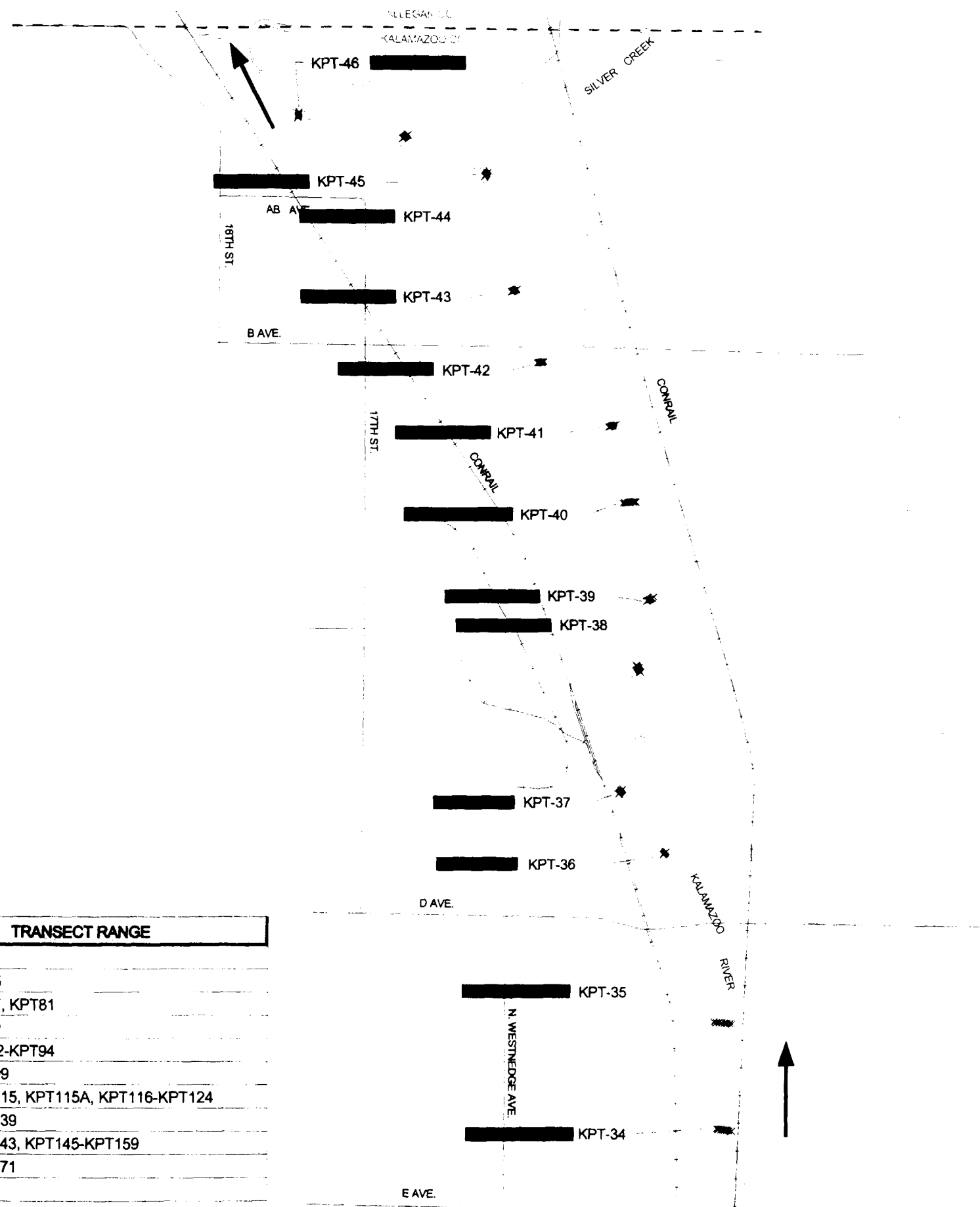
Note: Base map data derived from MIRIS. All transect locations surveyed. Discrepancies attributable to base map inaccuracy.



ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
TECHNICAL MEMORANDUM 10 SEDIMENT
CHARACTERIZATION & GEOSTATISTICAL PILOT STUDY

KALAMAZOO RIVER
DOWNSTREAM OF CONFLUENCE

FIGURE
3

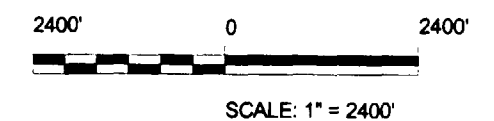


LEGEND

- RAILROAD RIGHT-OF-WAY
- APPROXIMATE DELINEATION OF PRESENT CREEK CHANNEL
- × SAMPLING LOCATION
- FINE SEDIMENT
- COARSE SEDIMENT
- ← DIRECTION OF FLOW

Each interval of a bar represents one sampling location along a transect. The left side of the bar corresponds with the left bank of the river looking downstream.

Note: Base map data derived from MIRIS. All transect locations surveyed. Discrepancies attributable to base map inaccuracy.

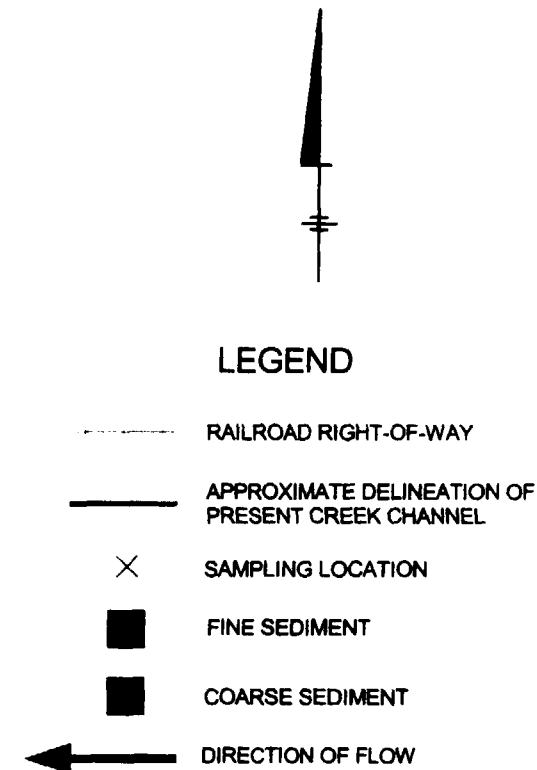
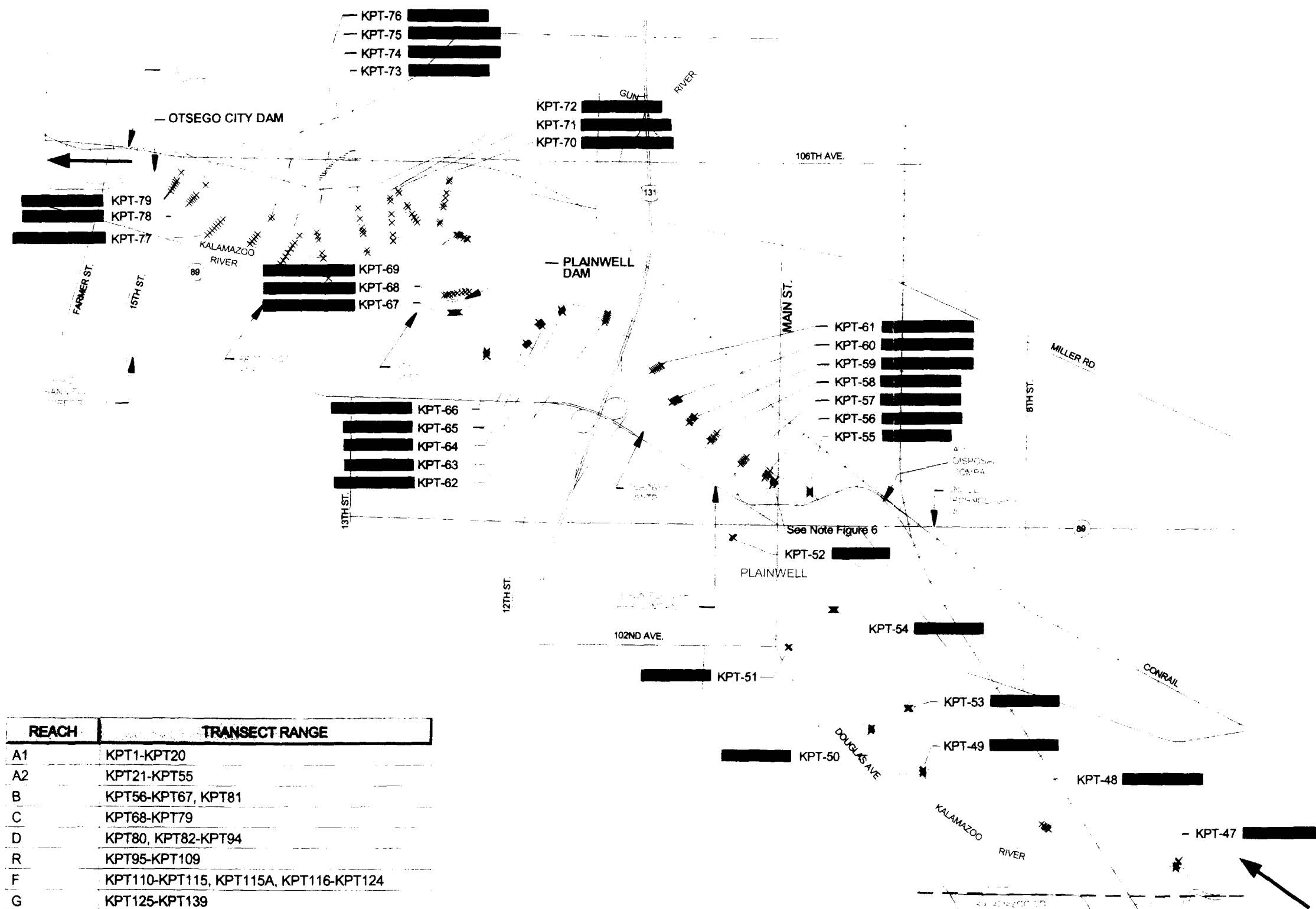


REACH	TRANSECT RANGE
A1	KPT1-KPT20
A2	KPT21-KPT55
B	KPT56-KPT67, KPT81
C	KPT68-KPT79
D	KPT80, KPT82-KPT94
R	KPT95-KPT109
F	KPT110-KPT115, KPT115A, KPT116-KPT124
G	KPT125-KPT139
H	KPT140-KPT143, KPT145-KPT159
	KPT160-KPT171
	PPT1-PPT15

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
TECHNICAL MEMORANDUM TO SEDIMENT
CHARACTERIZATION & GEOSTATISTICAL PILOT STUDY

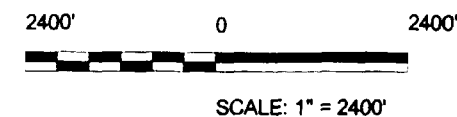
KALAMAZOO RIVER
UPSTREAM OF PLAINWELL

FIGURE
4



Each interval of a bar represents one sampling location along a transect. The left side of the bar corresponds with the left bank of the river looking downstream.

Note: Base map data derived from MIRIS. All transect locations surveyed. Discrepancies attributable to base map inaccuracy.

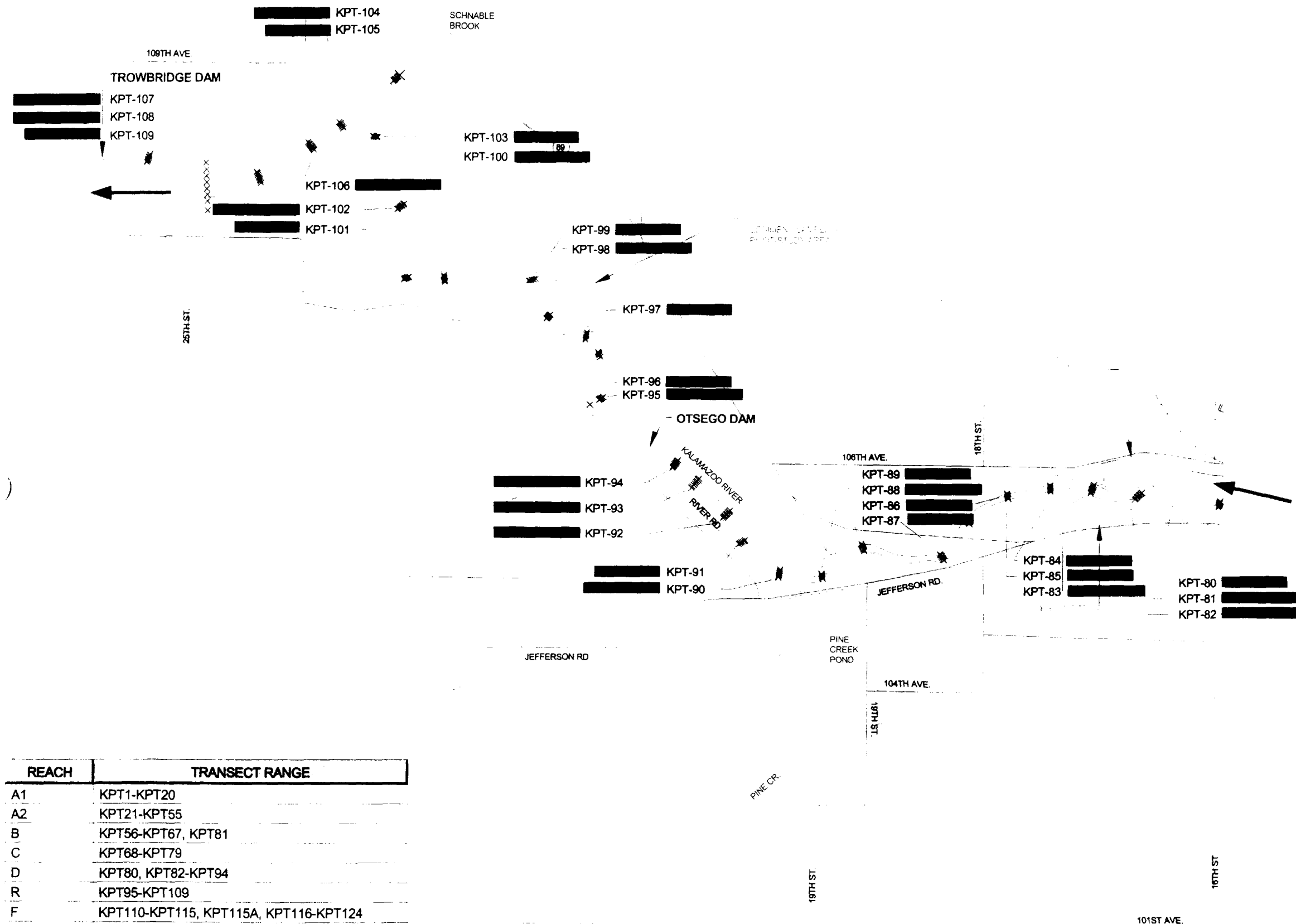


REACH	TRANSECT RANGE
A1	KPT1-KPT20
A2	KPT21-KPT55
B	KPT56-KPT67, KPT81
C	KPT68-KPT79
D	KPT80, KPT82-KPT94
R	KPT95-KPT109
F	KPT110-KPT115, KPT115A, KPT116-KPT124
G	KPT125-KPT139
H	KPT140-KPT143, KPT145-KPT159
I	KPT160-KPT171
P	PPT1-PPT15

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
TECHNICAL MEMORANDUM 10 SEDIMENT
CHARACTERIZATION AND TRANSFERENTIAL PLOTS STUDY

KALAMAZOO RIVER
OTSEGO CITY AND
FORMER PLAINWELL
IMPOUNDMENTS

FIGURE
5



- RAILROAD RIGHT-OF-WAY
- APPROXIMATE DELINEATION OF PRESENT CREEK CHANNEL
- X SAMPLING LOCATION
- FINE SEDIMENT
- COARSE SEDIMENT
- DIRECTION OF FLOW

Each interval of a bar represents one sampling location along a transect. The left side of the bar corresponds with the left bank of the river looking downstream.

Note: * Data for this transect inconsistent between BBL provided data sets.

Note: Base map data derived from MIRIS. All transect locations surveyed. Discrepancies attributable to base map inaccuracy.

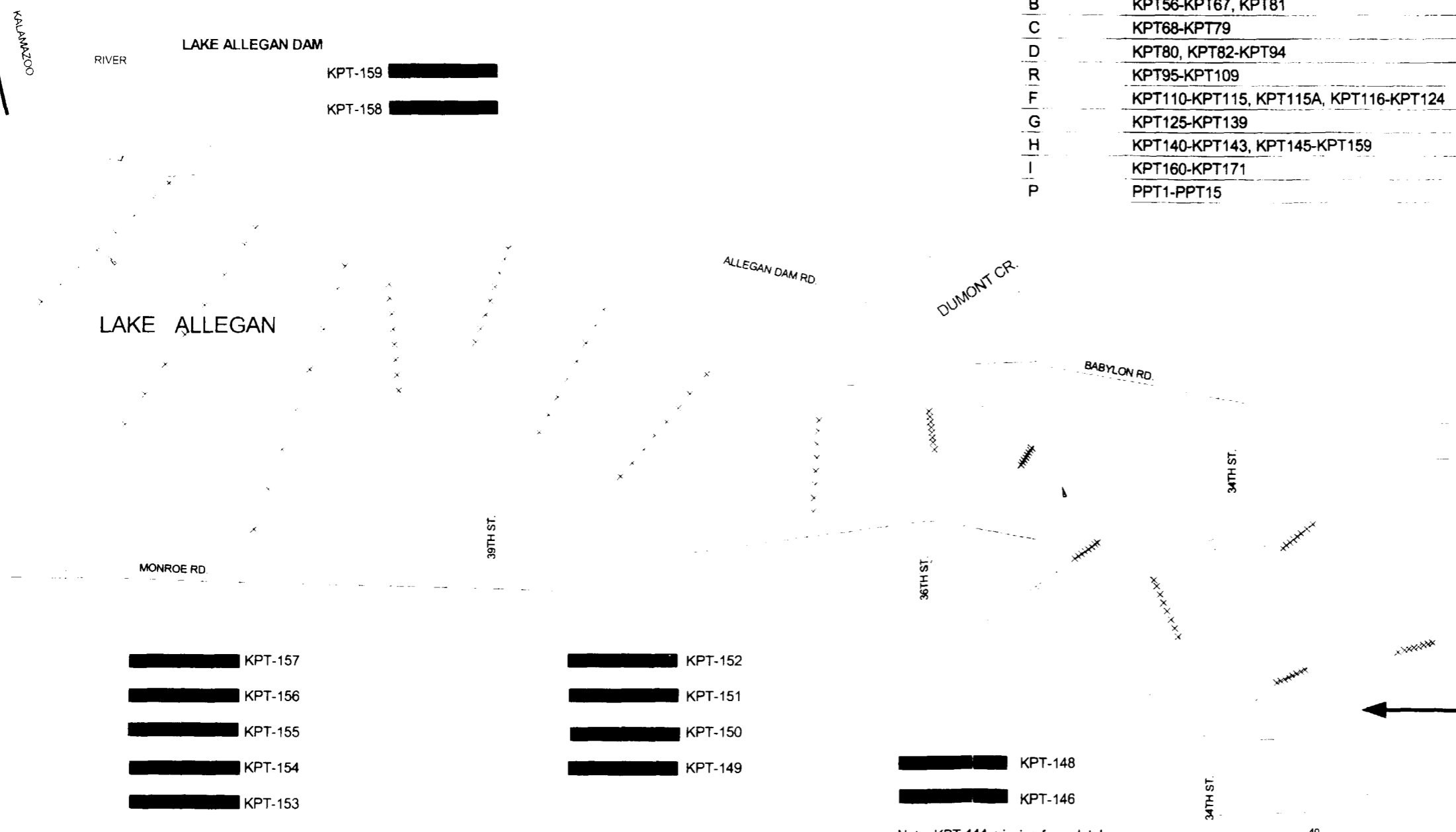
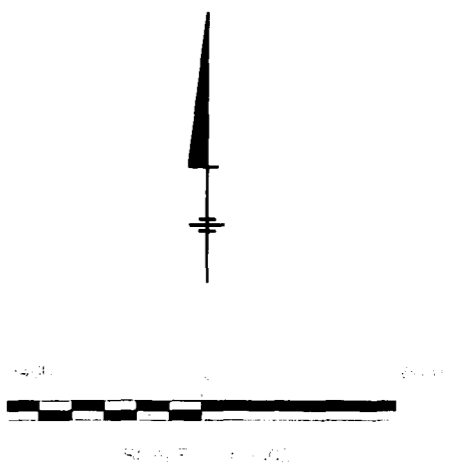
REACH	TRANSECT RANGE
A1	KPT1-KPT20
A2	KPT21-KPT55
B	KPT56-KPT67, KPT81
C	KPT68-KPT79
D	KPT80, KPT82-KPT94
R	KPT95-KPT109
F	KPT110-KPT115, KPT115A, KPT116-KPT124
G	KPT125-KPT139
I	KPT140-KPT143, KPT145-KPT159
P	KPT160-KPT171
	PPT1-PPT15

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
TECHNICAL MEMORANDUM TO SEDIMENT
CHARACTERIZATION & GEOSTATISTICAL ANALYSIS

KALAMAZOO RIVER
FORMER TROWBRIDGE AND
OTSEGO IMPOUNDMENTS

FIGURE
6

REACH	TRANSECT RANGE
A1	KPT1-KPT20
A2	KPT21-KPT55
B	KPT56-KPT67, KPT81
C	KPT68-KPT79
D	KPT80, KPT82-KPT94
R	KPT95-KPT109
F	KPT110-KPT115, KPT115A, KPT116-KPT124
G	KPT125-KPT139
H	KPT140-KPT143, KPT145-KPT159
I	KPT160-KPT171
P	PPT1-PPT15



LEGEND

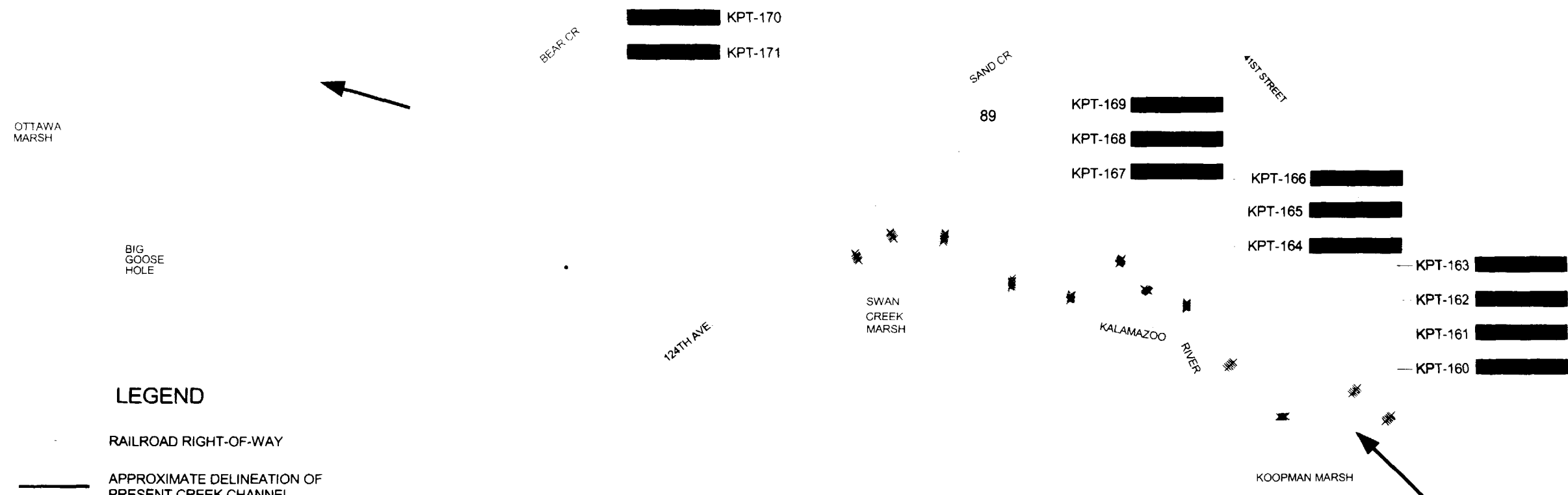
- RAILROAD RIGHT-OF-WAY
 - APPROXIMATE DELINEATION OF PRESENT CREEK CHANNEL
 - SAMPLING LOCATION
 - FINE SEDIMENT
 - COARSE SEDIMENT
 - DIRECTION OF FLOW
- Each interval of a bar represents one sampling location along a transect. The left side of the bar corresponds with the left bank of the river looking downstream.

Note: Base map data derived from MIRIS.
All transect locations surveyed.
Discrepancies attributable to base map inaccuracy.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
TECHNICAL MEMORANDUM TO SUPERFUND
WATER QUALITY MONITORING & SEDIMENTATION STUDY

LAKE ALLEGAN

FIGURE 8



LEGEND

- RAILROAD RIGHT-OF-WAY
- APPROXIMATE DELINEATION OF PRESENT CREEK CHANNEL
- SAMPLING LOCATION
- FINE SEDIMENT
- COARSE SEDIMENT
- DIRECTION OF FLOW

Each interval of a bar represents one sampling location along a transect. The left side of the bar corresponds with the left bank of the river looking downstream.

Note: Base map data derived from MIRIS. All transect locations surveyed. Discrepancies attributable to base map inaccuracy.

REACH	TRANSECT RANGE
A1	KPT1-KPT20
A2	KPT21-KPT55
B	KPT56-KPT67, KPT81
C	KPT68-KPT79
D	KPT80, KPT82-KPT94
R	KPT95-KPT109
F	KPT110-KPT115, KPT115A, KPT116-KPT124
G	KPT125-KPT139
H	KPT140-KPT143, KPT145-KPT159
I	KPT160-KPT171
P	PPT1-PPT15

0 2400' 4800'
SCALE: 1" = 2400'

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

KALAMAZOO RIVER
LAKE ALLEGAN DAM
TO OTTAWA MARSH

FIGURE
9

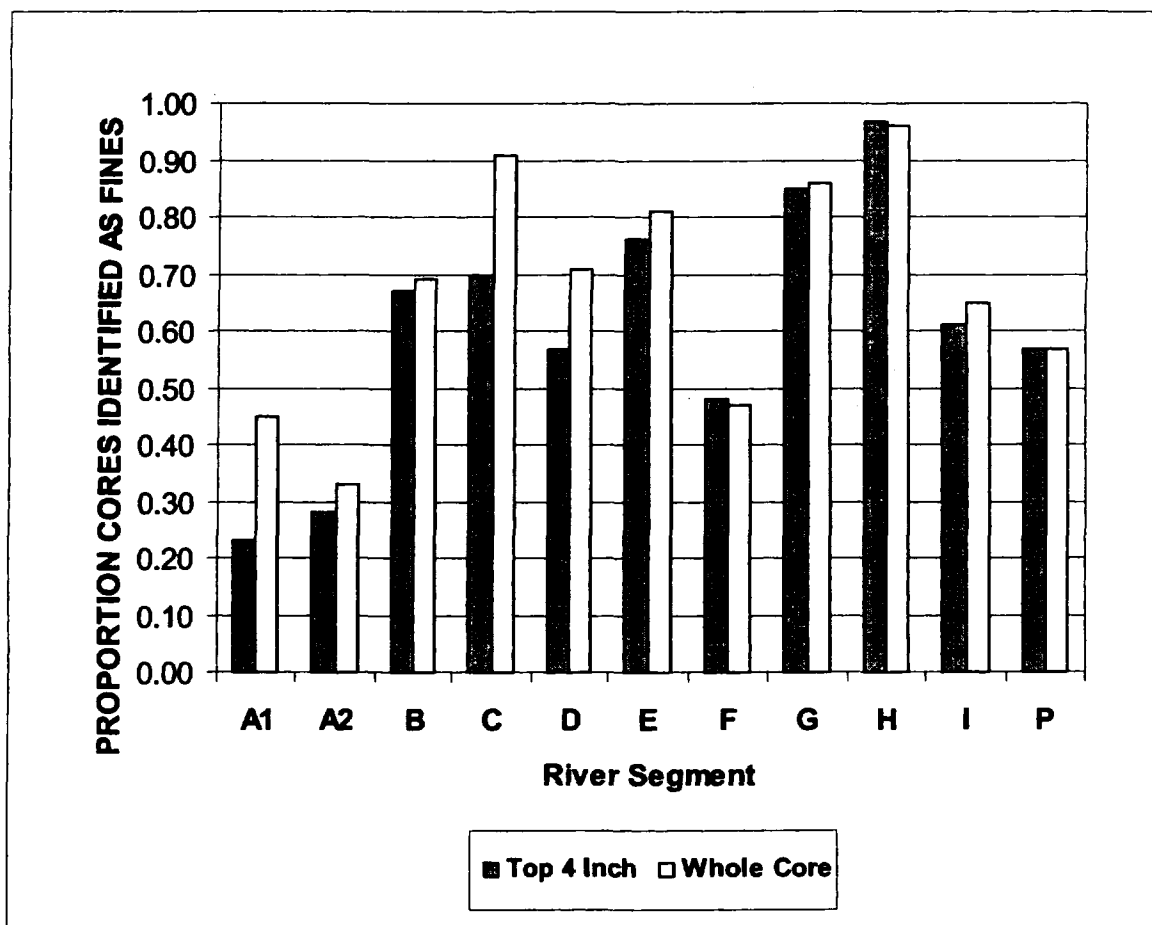


Figure 10. Percent of cores collected classified as containing fine-grained sediment by river segment. Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site, Technical Memorandum 10 Sediment Characterization/Geostatistical Pilot Study.

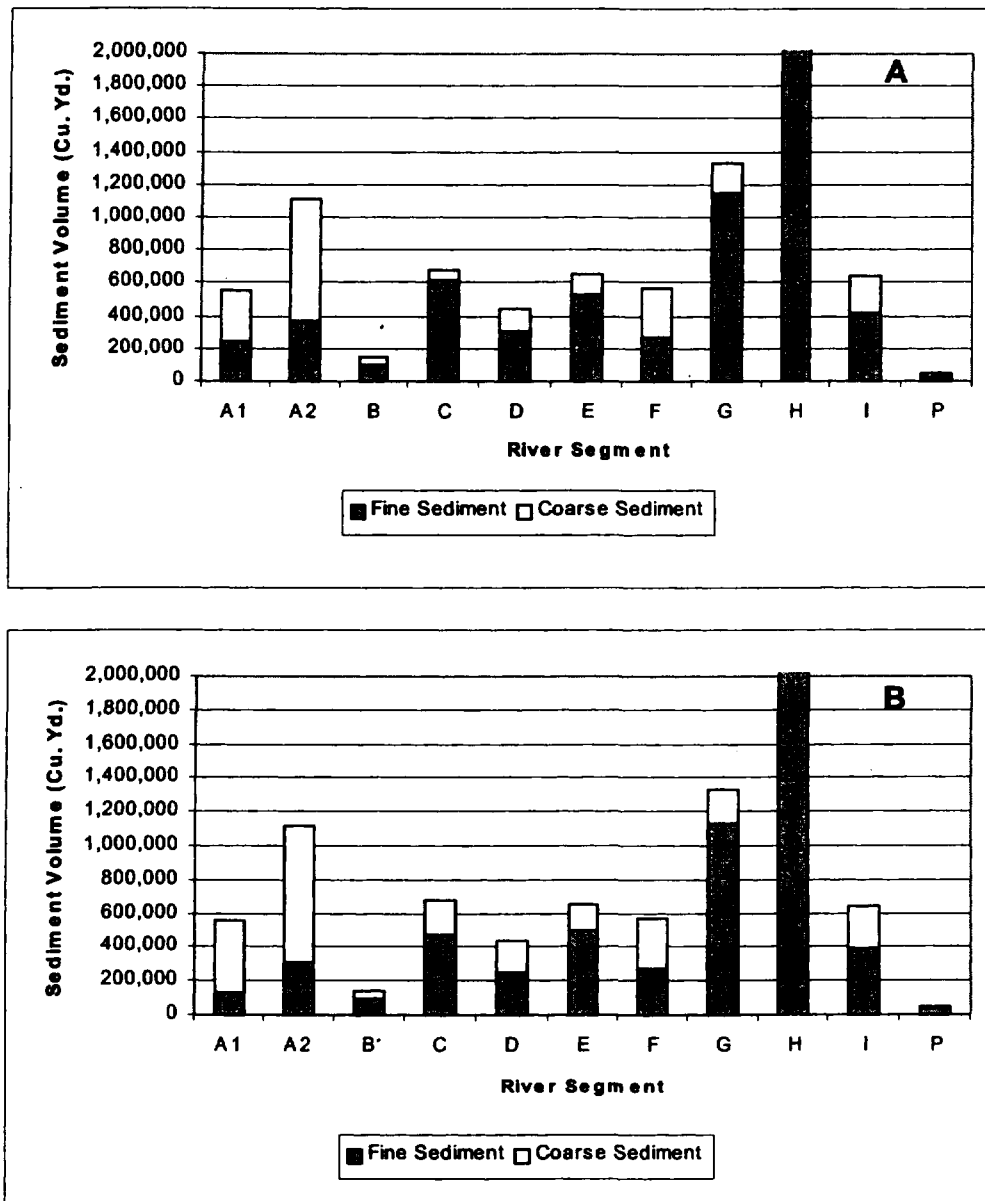
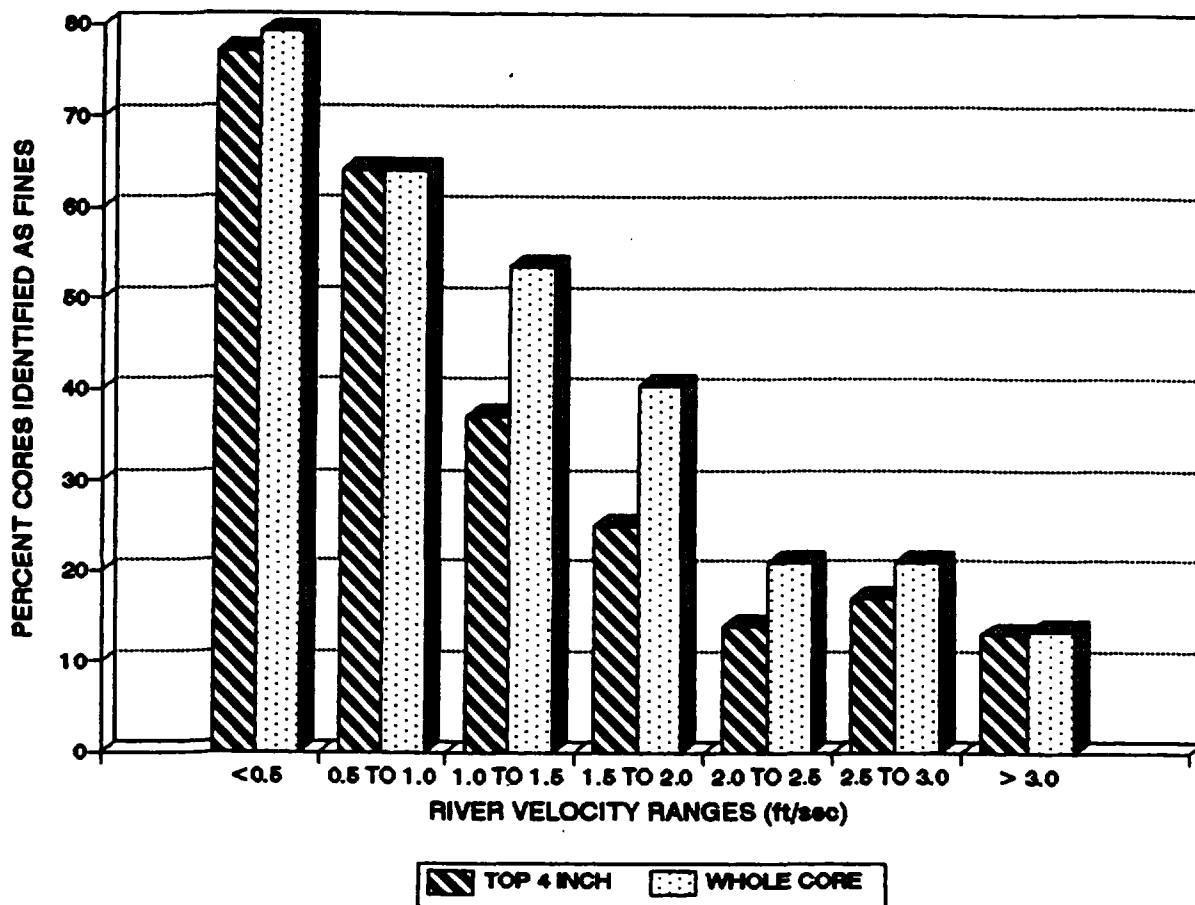


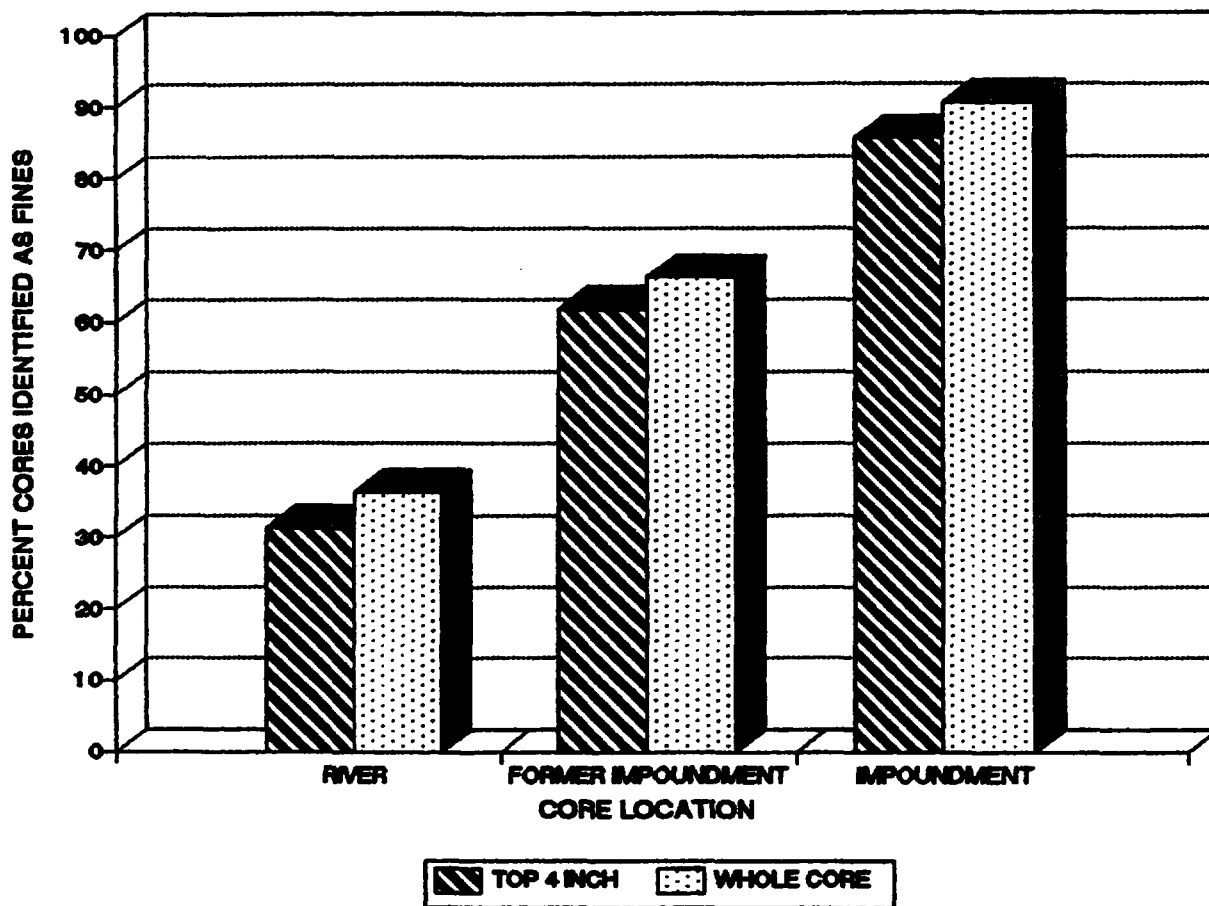
Figure 11. Volume of fine- and coarse-grained sediments based on classification by the top four inches (Panel A) and whole core (Panel B) in the Kalamazoo River, Allied Paper, Inc./Portage Creek/Kalamazoo River superfund Site, Technical Memorandum 10, Sediment Characterization/Geostatistical Pilot Study. Reach H contained over 25,000,000 (Cu. Yd.) of sediments which were 97 and 96 percent fine-grained based on the top 4 inches and whole core respectively.



ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
 TECHNICAL MEMORANDUM 10 SEDIMENT
 CHARACTERIZATION/GEOSTATISTICAL PILOT STUDY

**PERCENT OF CORES CLASSIFIED
 AS CONTAINING FINE-GRAINED
 SEDIMENT BY VELOCITY RANGE**

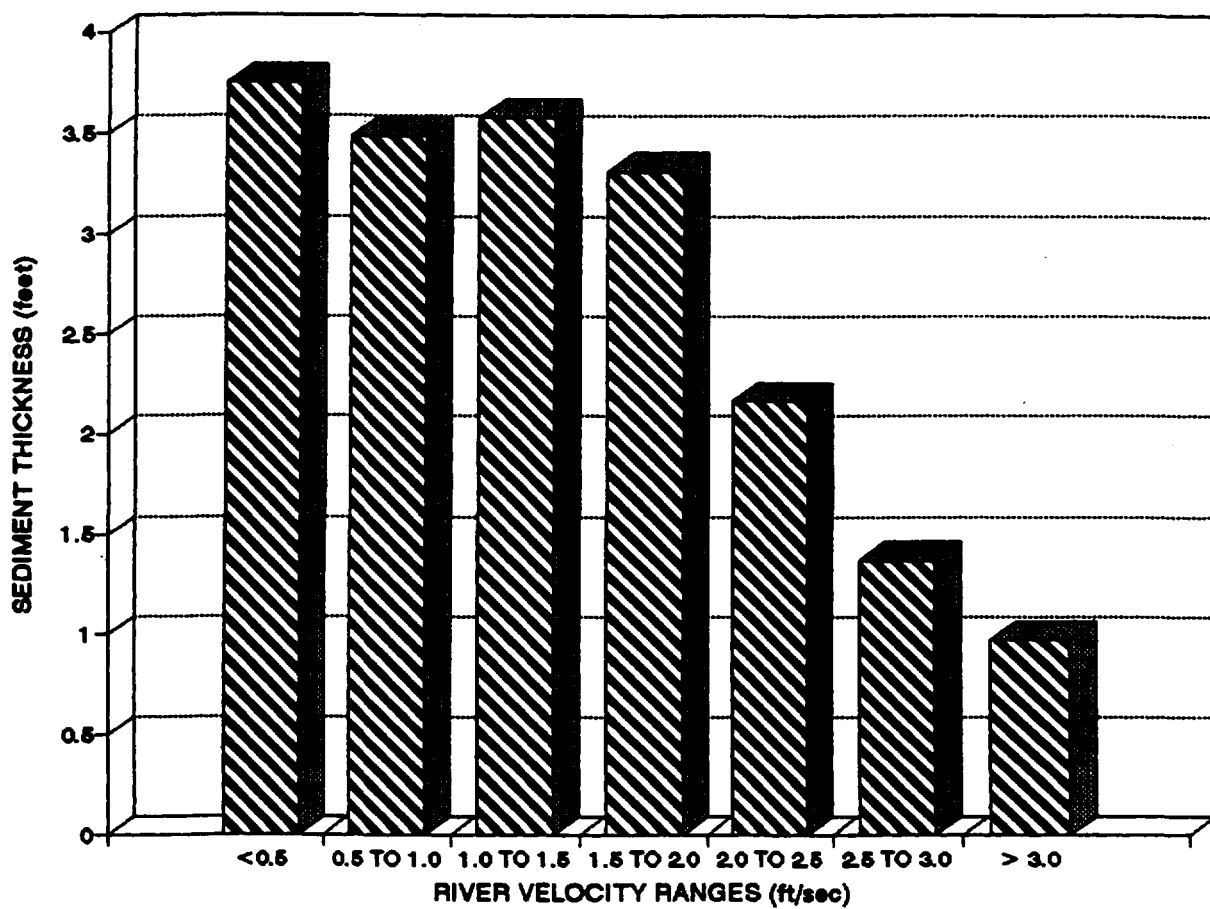
**FIGURE
 12**



ALLIED PAPER, INC./PORTAGE CREEK KALAMAZOO RIVER SUPERFUND SITE
 TECHNICAL MEMORANDUM 10 SEDIMENT
 CHARACTERIZATION GEOSTATISTICAL PILOT STUDY

**PERCENT OF CORES CLASSIFIED AS
 CONTAINING FINE-GRAINED SEDIMENT
 BY CHANNEL CHARACTERISTIC**

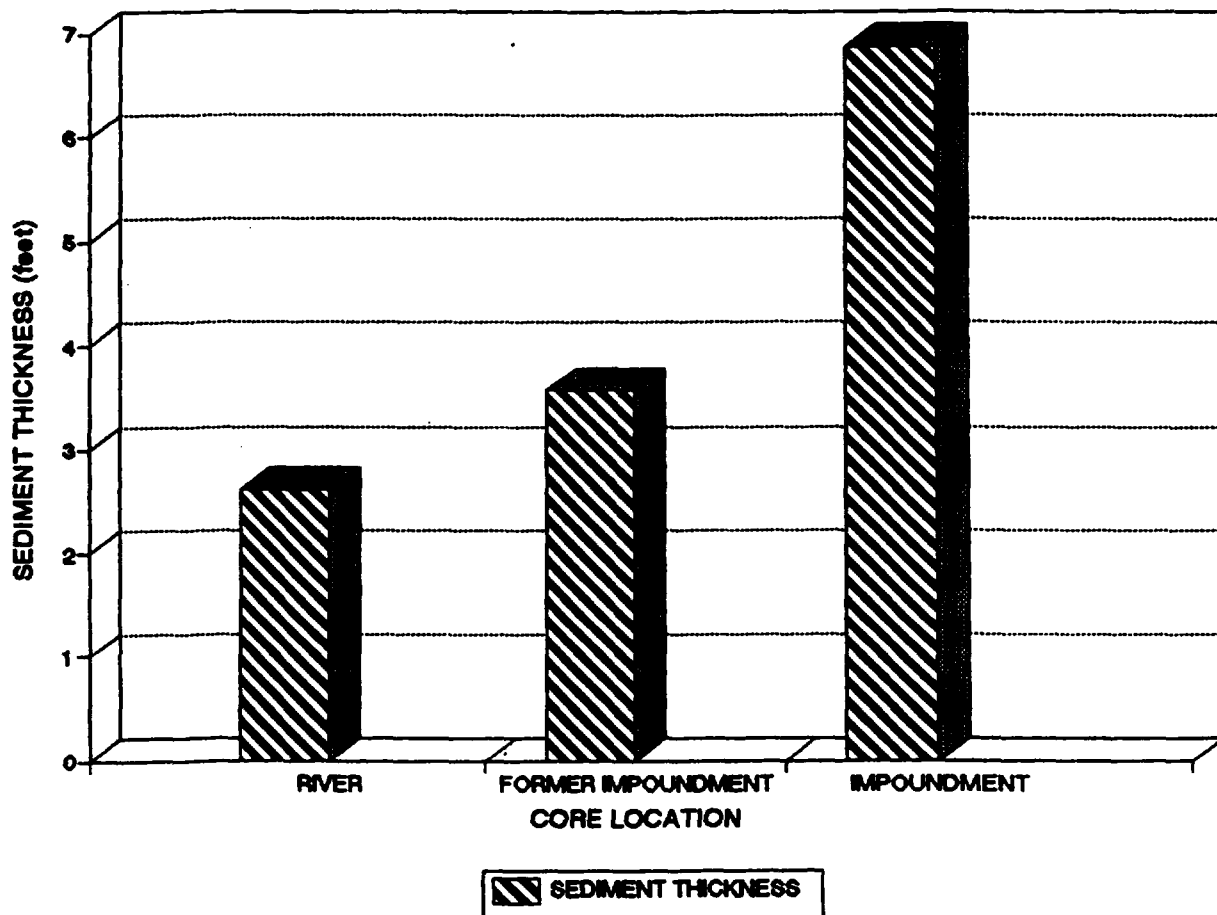
**FIGURE
 13**



ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
 TECHNICAL MEMORANDUM 10 SEDIMENT
 CHARACTERIZATION/GEOSTATISTICAL PILOT STUDY

SEDIMENT THICKNESS BY VELOCITY RANGE

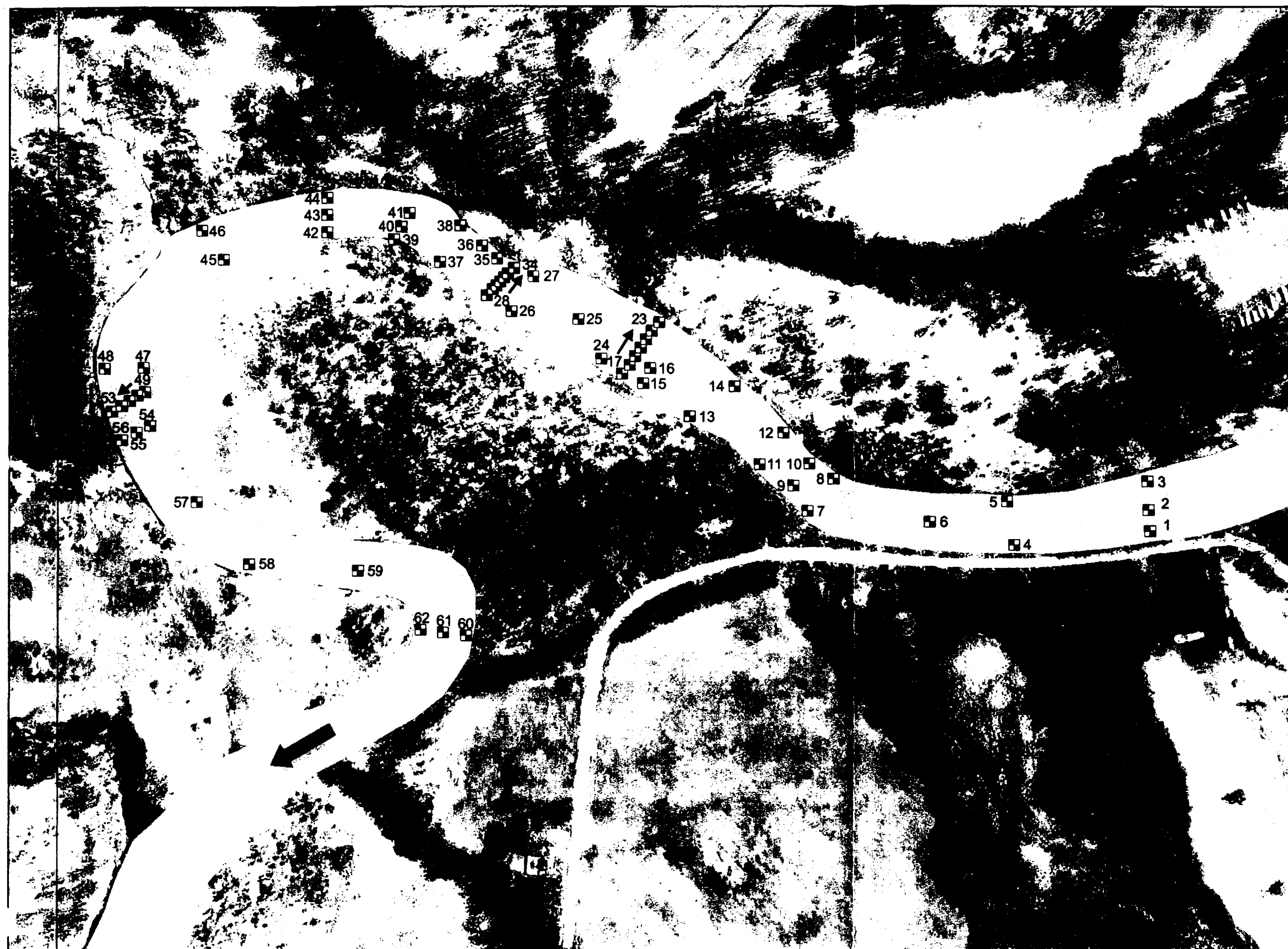
FIGURE
14



ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
TECHNICAL MEMORANDUM 10 SEDIMENT
CHARACTERIZATION/GEOSTATISTICAL PILOT STUDY

**SEDIMENT THICKNESS
BY CHANNEL CHARACTERISTICS**

FIGURE
15

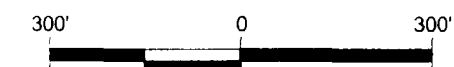


LEGEND

 SEDIMENT SAMPLING SITES

NOTE:

1. Aerial photo by Lockwood Mapping, 4/91.
Scanned at an approximate scale of 1" = 600'.
2. Sample locations are approximate.

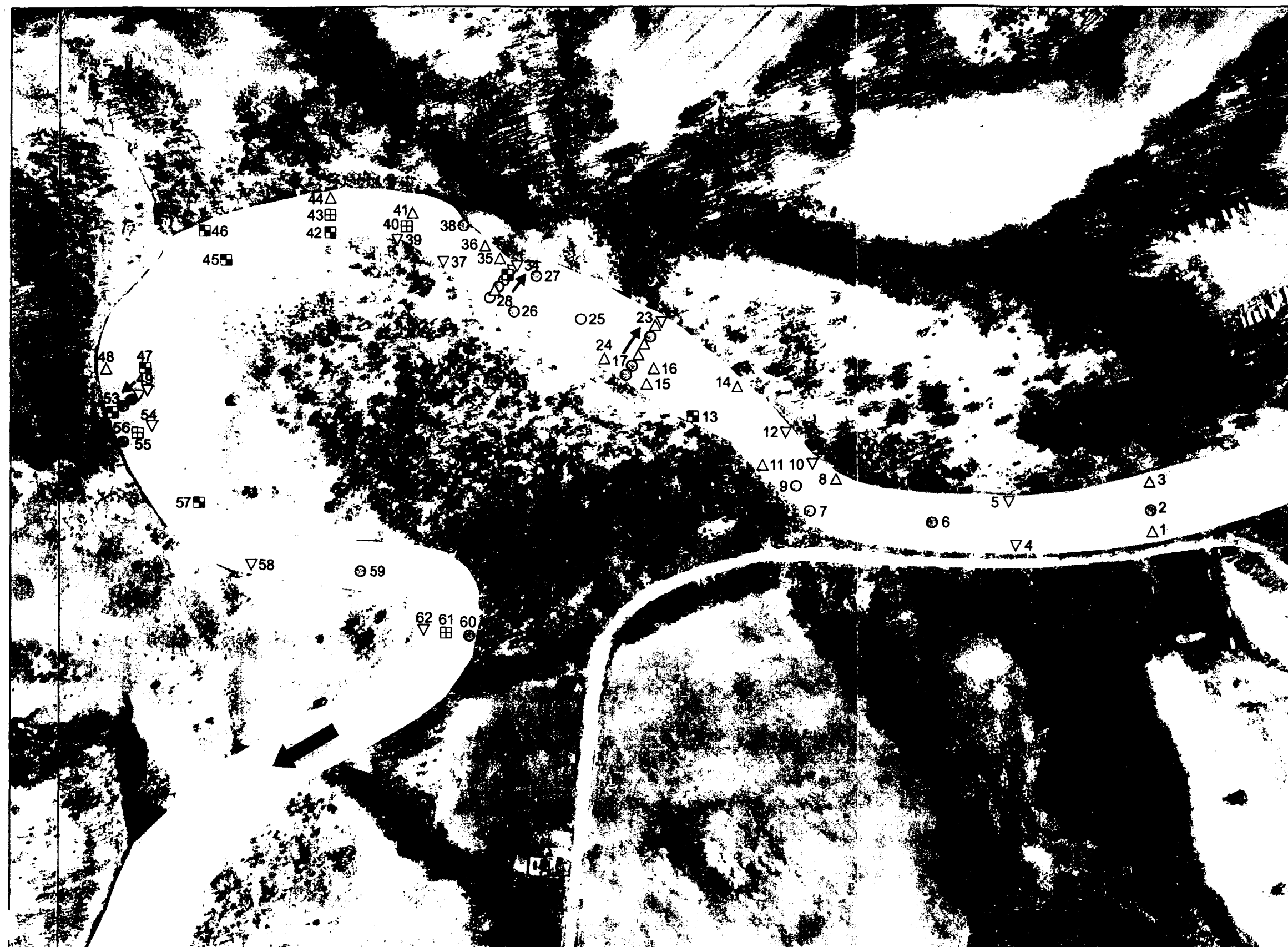


APPROXIMATE SCALE: 1" = 300'

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
TECHNICAL MEMORANDUM 10 SEDIMENT
CHARACTERIZATION/GEOSTATISTICAL PILOT STUDY

SAMPLE LOCATIONS FOR
GEOSTATISTICAL PILOT STUDY

FIGURE
16



CONCENTRATION RANGES

- = > 1 mg/kg
- ▽ = 0.1 to 1 mg/kg
- △ = < 0.1 mg/kg
- = Below Detection Limit
- ⊠ = No Sample Obtained

NOTES:

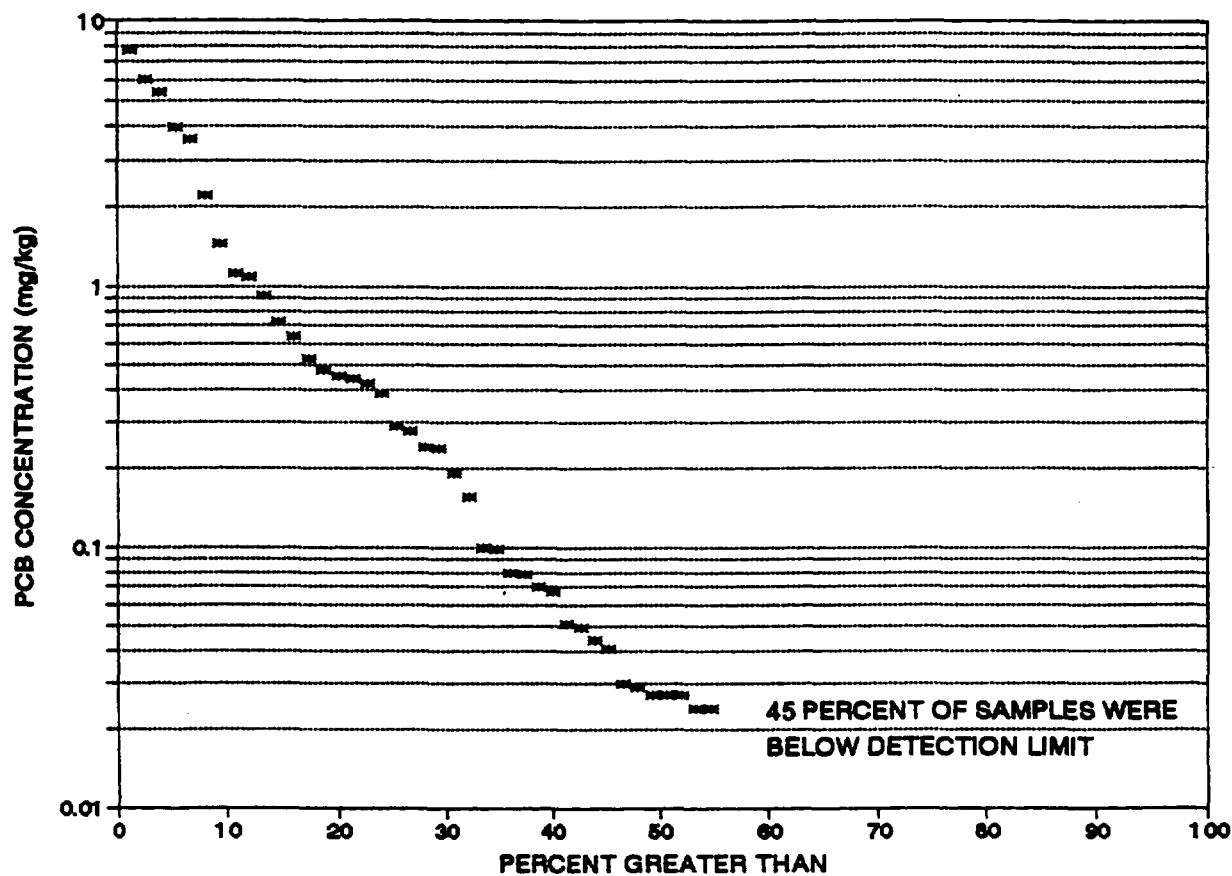
1. Aerial photo by Lockwood Mapping, 4/91.
Scanned at an approximate scale of 1" = 600'.
2. Where multiple samples exist for a core the highest concentration was used.
3. Sample locations are approximate.

300' 0 300'

APPROXIMATE SCALE: 1" = 300'

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 CHARACTERIZATION/GEOSTATISTICAL PILOT STUDY

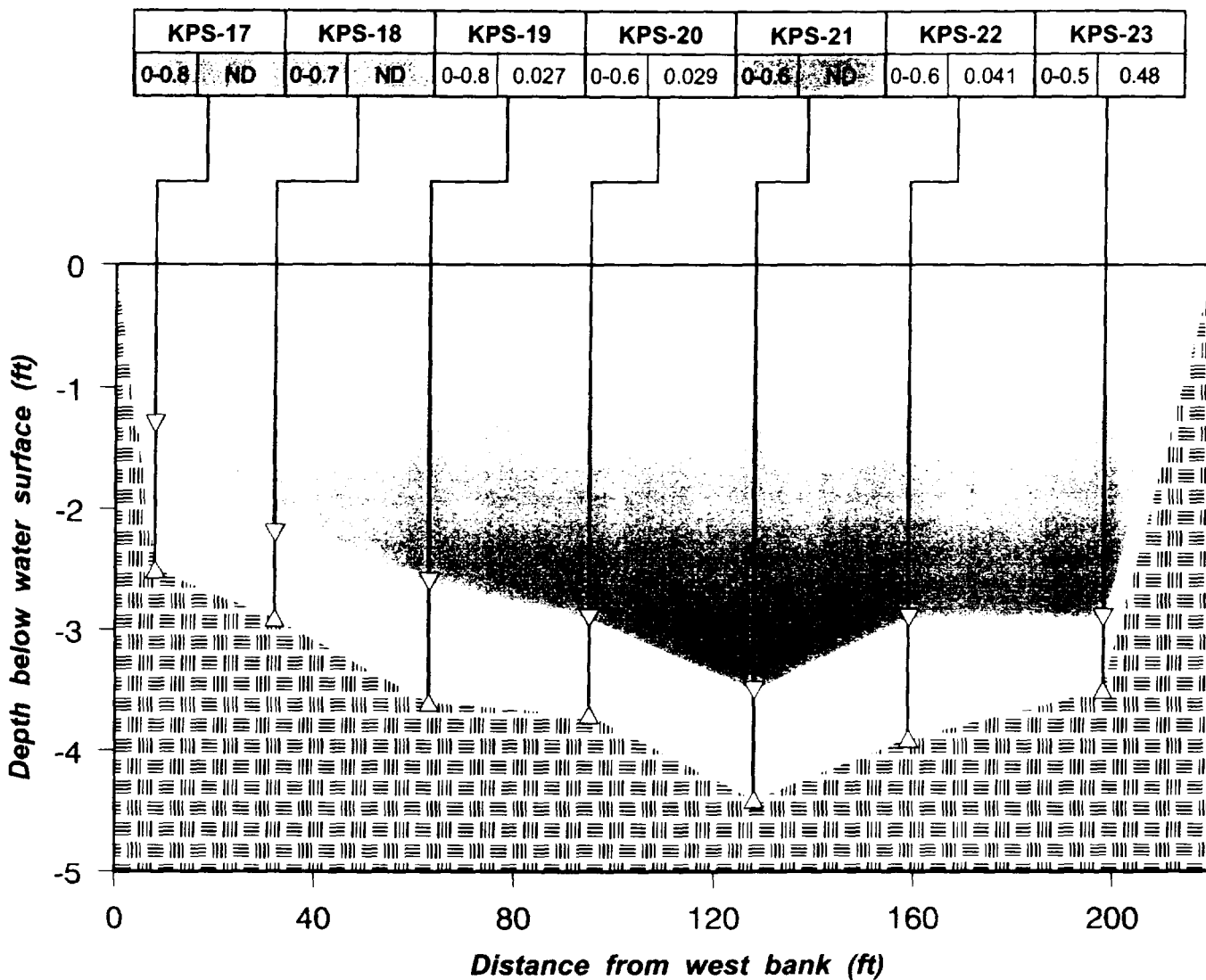
GEOSTATISTICAL PILOT STUDY SEDIMENT SAMPLE PCB CONCENTRATION RANGES



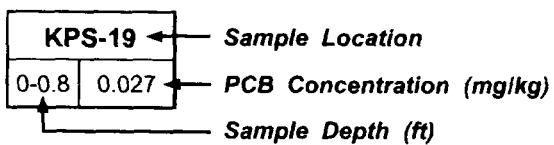
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**GEOSTATISTICAL
PILOT STUDY PCB CONCENTRATION
FREQUENCY DISTRIBUTION**

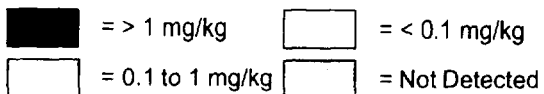
**FIGURE
18**



LEGEND



CONCENTRATION RANGES

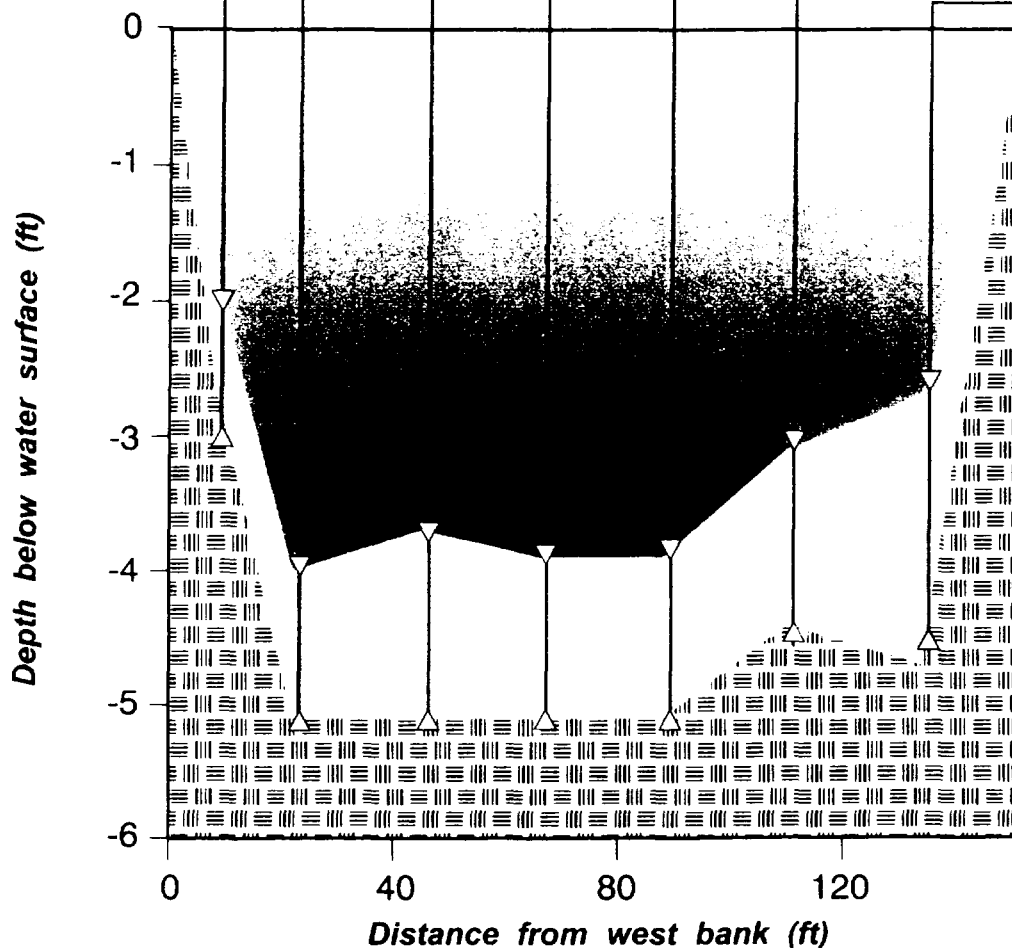


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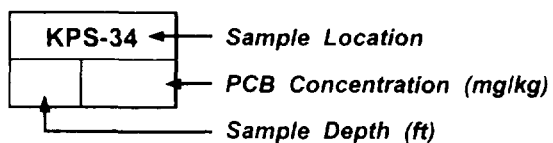
RIVER CROSS SECTION KPS-17 TO KPS-23

**FIGURE
19**

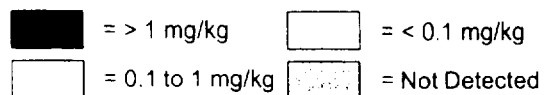
KPS-28	KPS-29	KPS-30	KPS-31	KPS-32	KPS-33	KPS-34
0-1	0-1	0.10			0-1	0.64



LEGEND



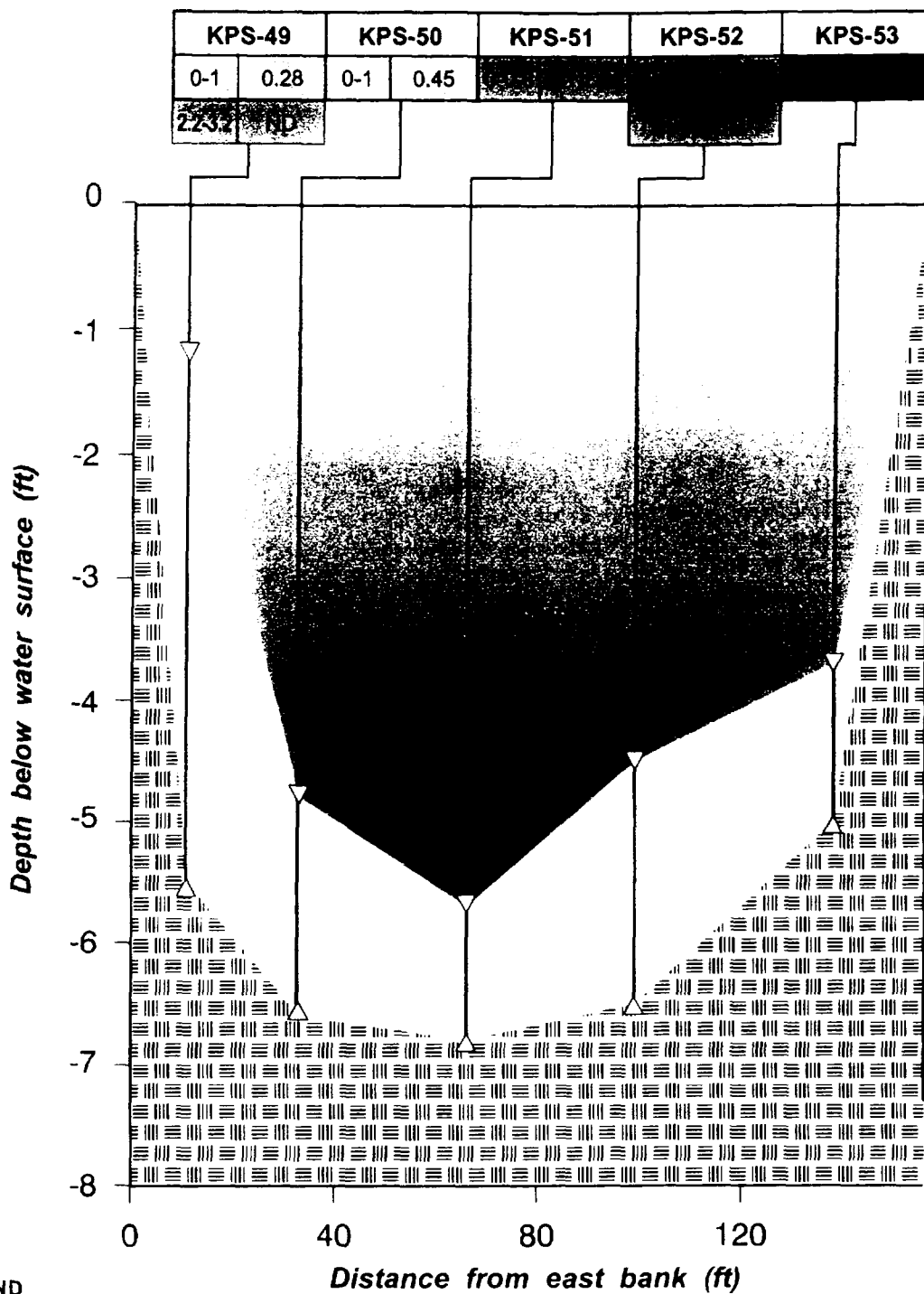
CONCENTRATION RANGES



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RIVER CROSS SECTION KPS-28 TO KPS-34

FIGURE
20



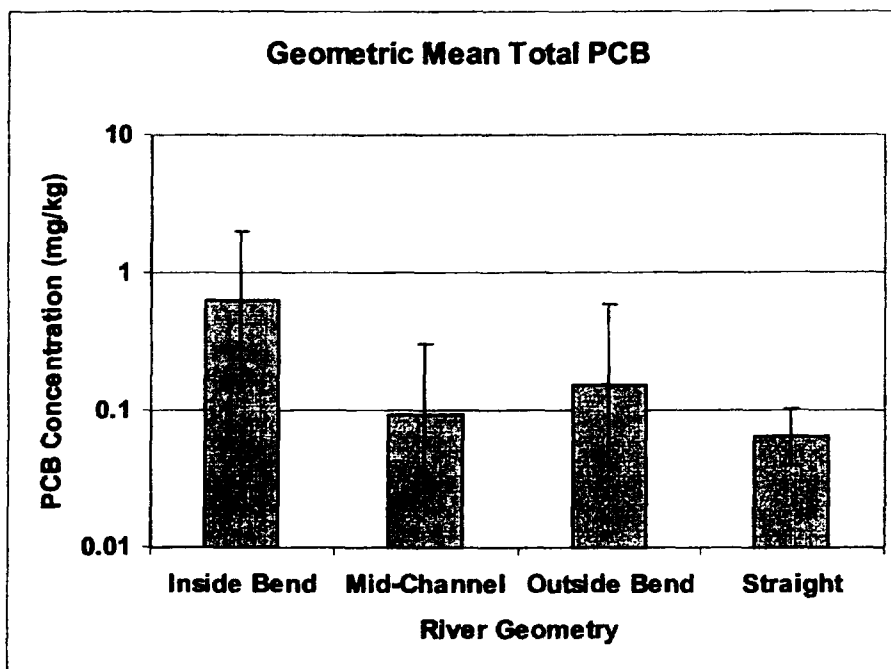
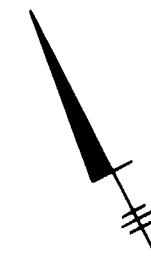


Figure 22. Geometric mean PCB concentration with approximate 95% confidence limits classified by sample position relative to river geometry, Kalamazoo River, Allied Paper, Inc./Portage Creek/Kalamazoo River superfund Site, Technical Memorandum 10, Sediment Characterization/Geostatistical Pilot Study.

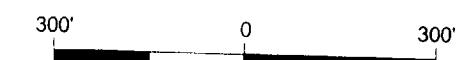


Concentration Ranges

- = > 1 mg/kg
- = 0.3 to 1 mg/kg
- = 0.1 to 0.3 mg/kg
- = 0.03 to 0.1 mg/kg
- = 0.01 to 0.03 mg/kg
- = < 0.01 mg/kg

NOTES:

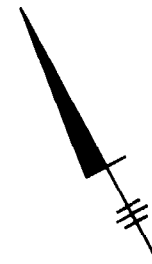
1. Aerial photo by Lockwood Mapping, 4/91.
Scanned at an approximate scale of 1" = 600'.
2. PCB concentration ranges generated with GeoEAS software.









APPROXIMATE SCALE: 1" = 300'

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TECHNICAL MEMORANDUM 10 SEDIMENT
CHARACTERIZATION/GEOSTATISTICAL PILOT STUDY

**KRIGED GEOMETRIC MEAN
PCB CONCENTRATIONS**



Concentration Ranges

-  = > 1 mg/kg
-  = 0.3 to 1 mg/kg
-  = 0.1 to 0.3 mg/kg
-  = 0.03 to 0.1 mg/kg
-  = 0.01 to 0.03 mg/kg
-  = < 0.01 mg/kg

NOTES:

1. Aerial photo by Lockwood Mapping, 4/91.
Scanned at an approximate scale of 1" = 600'.
2. PCB concentration ranges generated with GeoEAS software.

300' 0 300'

APPROXIMATE SCALE: 1" = 300'

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TECHNICAL MEMORANDUM 10 SEDIMENT
CHARACTERIZATION/GEOSTATISTICAL PILOT STUDY

**KRIGED GEOMETRIC MEAN
PCB CONCENTRATION PLUS
ONE STANDARD DEVIATION**

**FIGURE
24**



Concentration Ranges

- = > 1 mg/kg
- = 0.3 to 1 mg/kg
- = 0.1 to 0.3 mg/kg
- = 0.03 to 0.1 mg/kg
- = 0.01 to 0.03 mg/kg
- = < 0.01 mg/kg

NOTES:

1. Aerial photo by Lockwood Mapping, 4/91.
Scanned at an approximate scale of 1" = 600'.
2. PCB concentration ranges generated with GeoEAS software.

300' 0 300'

APPROXIMATE SCALE: 1" = 300'

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
TECHNICAL MEMORANDUM 10 SEDIMENT
CHARACTERIZATION/GEOSTATISTICAL PILOT STUDY

**KRIGED GEOMETRIC MEAN
PCB CONCENTRATION MINUS
ONE STANDARD DEVIATION**

**FIGURE
25**

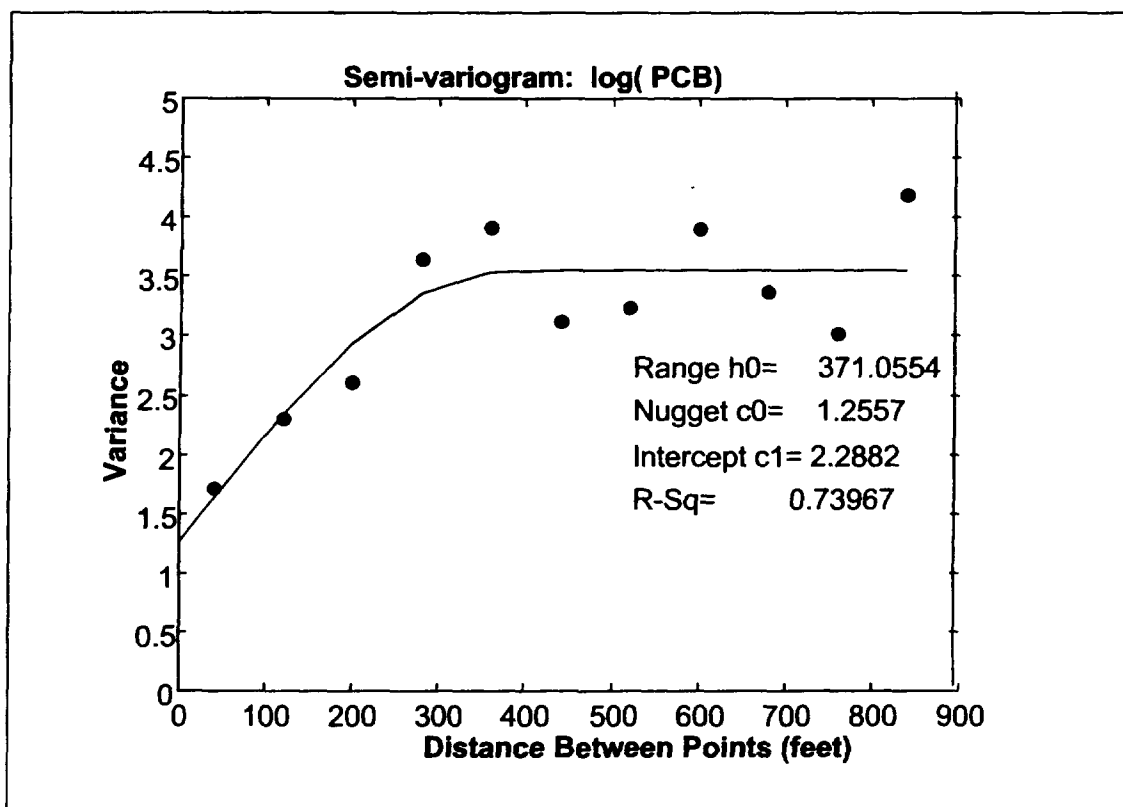


Figure 26. Along river channel, sample variogram estimates for natural log transformed surficial total PCB concentration, Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund site, Technical Memorandum 10 sediment Characterization/Geostatistical Pilot Study. Observations that below detection limits were replaced with uniformly distributed random numbers between zero and detection limits.

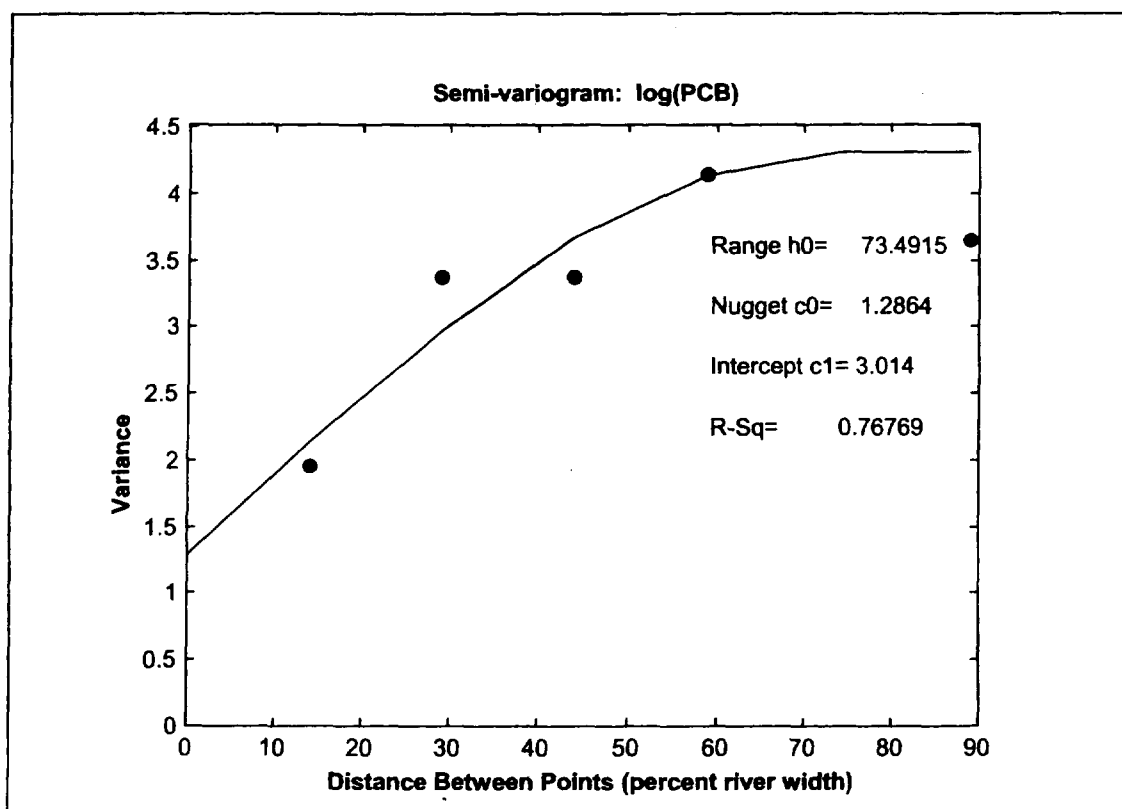


Figure 27. Across river channel, sample variogram estimates for natural log transformed surficial total PCB concentration, Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund site, Technical Memorandum 10 sediment Characterization/Geostatistical Pilot Study. Observations that were below detection limits were replaced with uniformly distributed random numbers between zero and detection limits.